CANADA'S GREENHOUSE GAS INVENTORY

GHG Trends Information from Environment Canada's Greenhouse Gas Division

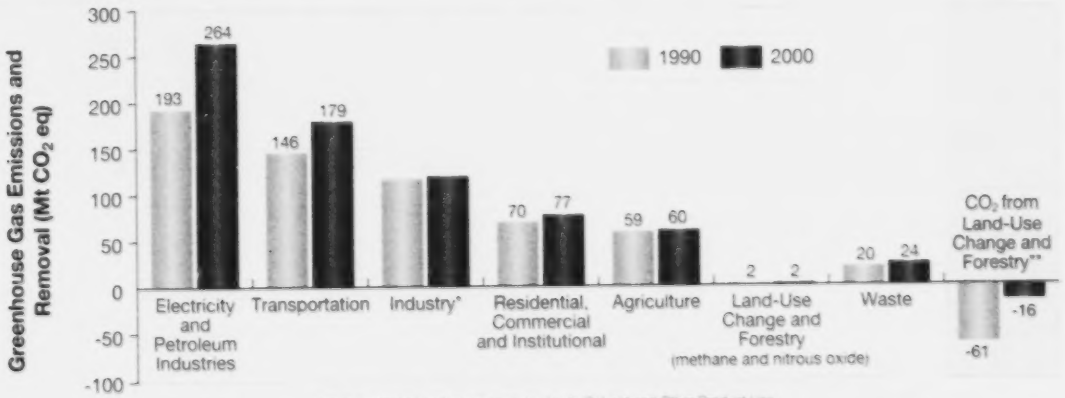
Overview: 1990-2000

Total Canadian emissions of greenhouse gases to the atmosphere were estimated to be 726 megatonnes carbon dioxide equivalent* (Mt CO_2 eq) in 2000, up 3.2% over 1999 levels. This year-to-year rate of increase is the second highest since 1990 and is largely a result of above average increases in energy use for heating and an increase in overall productivity in the Canadian economy, which was 4.6% greater in 2000 than 1999. Between 1990 and 2000, emissions increased 19.6%, or 119 Mt, while Canada's Gross Domestic Product (GDP) grew nearly 33%, total domestic energy consumption increased 17%, and population rose 11%.

- On a greenhouse gas basis, carbon dioxide was the dominant gas, accounting for 78.7% (571 Mt) of 2000 emissions, while methane and nitrous oxide contributed the next largest shares at 12.6% (91 Mt) and 7.4% (54 Mt), respectively.
- The greatest sector contributions to emissions in 2000 are from the Electricity and Petroleum Industries, which accounted for 36% of total national emissions (264 Mt), and the Transportation sector, which contributed 25% (179 Mt). These sectors are also responsible for nearly all of the growth in Canadian emissions since 1990. This is mainly the result of an increase in fossil fuel consumption for electricity generation, a rise in transportation energy consumption, as well as growth in fossil fuel production, largely for export.
- The Industry sector exhibited a 1% increase in emissions between 1990 and 2000, despite significant increases in sector GDP and production. The stability in emissions is largely due to a decline in process emissions from adipic acid production, as well as increased energy efficiency and fuel substitution. Other sectors, such as Residential, Commercial and Institutional (RCI), Agriculture, and Waste, contributed 11% to the total emissions growth over the period.
- Net carbon dioxide removals by sinks associated with the Land-Use Change and Forestry sector declined 73% since 1990, but are not included in the national inventory totals.

*Unless other wise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a relative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.

Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000



*Value illustrated includes emissions due to Solvent and Other Product Use

**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals

Canada's Greenhouse Gas Inventory (CGHGI)

The Canadian Greenhouse Gas Inventory is developed, compiled, and reported annually by the Greenhouse Gas Division of Environment Canada. The inventory is prepared in accordance with the Framework Convention on Climate Change (UNFCCC) and particularly Decision 3/C.P. 5 which states Annex 1 parties should annually submit by April 15 national inventories in accordance with the UNFCCC Guidelines on annual inventories (UNFCCC/CP/1999/7).

Canada's Greenhouse Gas Inventory 1990-2000: Trends Fact Sheet Series

The 1990-2000 CGHGI Fact Sheet Series provides a discussion of the trends in Canadian greenhouse gas emissions and removals on a sector basis, and presents an understanding of the nature, causes and sources of the trends. Methodologies for estimating quantities of emissions and removals, while not included in the fact sheet series, will be detailed in Environment Canada's upcoming report entitled, *Canada's Greenhouse Gas Inventory 1990-2000*, due for release later in 2002.

In addition to this fact sheet, which contains a national overview of Canada's greenhouse gas trends since 1990, the 2000 CGHGI Fact Sheet Series will also include detailed trends analyses in the following seven sectors* :

1. **Electricity and Petroleum Industries:** is comprised of two sectors:
   - *Electricity Generation* - includes emissions from fuel combustion; and
   - *Petroleum Industries* - includes fuel combustion, industrial process and fugitive emissions within the upstream (e.g. oil and gas exploration, production and transport) and downstream (e.g. refining of oil products and natural gas distribution) petroleum industry sub-sectors.
2. **Transportation:** includes fuel combustion emissions from mobile sources - on-road, air, marine, rail, and off-road modes.
3. **Industry:** consists of fuel combustion, industrial process and fugitive emissions from a diverse array of industries - from steel, auto, and electronic manufacturing to pharmaceutical, fertiliser, pulp and paper and food production.
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6. **Land-Use Change and Forestry:** includes greenhouse gas emissions and removals from changes in forest and other woody biomass stocks, human-induced fires, and land-use changes.
7. **Waste:** includes emissions from solid waste disposal on land, wastewater handling and waste incineration.

*The remaining fact sheets in the 2000 series will be available later in 2002.

Inventory estimates are determined by methods and models developed in-house by engineering and scientific staff, as well as from published data, data developed by industry, or methods developed by the Intergovernmental Panel on Climate Change (IPCC, 1997).

The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydro fluorocarbons (HFCs).

The inventory uses an internationally agreed to reporting format that groups emissions and removals into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry, and Waste.

The 2000 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, use a modified sector approach to facilitate the use of information by the public.

Canada's Gross Domestic Product (GDP) has been growing more rapidly as greenhouse gas emission growth has slowed.

Year	Annual Growth in GHG Emissions (%)	Annual Growth in GDP* (%)
1991	-1.2%	-1.9%
1992	2.7%	1.0%
1993	0.4%	2.4%
1994	3.6%	4.8%
1995	2.7%	2.7%
1996	2.1%	1.5%
1997	1.4%	4.5%
1998	1.1%	4.0%
1999	2.0%	5.2%
2000	3.2%	4.6%

* Statistics Canada, Table 384-0002

National Trends

Total Canadian emissions of greenhouse gases in 2000 were 726 Mt, 19.6% higher than the 1990 level of 607 Mt. In the short-term, emissions rose 3.2% since 1999. This is the second highest annual growth rate of the decade and is largely a result of above average increases in energy use for heating and an increase in overall productivity in the Canadian economy, which was 4.6% greater in 2000 than 1999. In 1994, emissions

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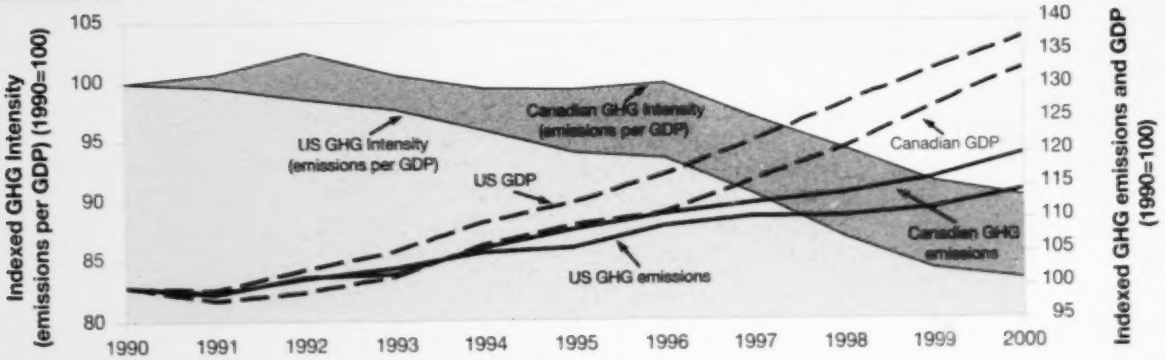
Figure 2 Trends in Greenhouse Gas Emissions, GDP and Greenhouse Gas Intensity (GHG Intensity) for Canada and the United States, 1990 to 2000



Percent Growth Between 1990-2000

Total Growth in GDP		Total Growth in Emissions	
Canada	33%	Canada	19.6%
US	37%	US	14.1%

Sources: Canadian GHG: Environment Canada, *Canada's Greenhouse Gas Inventory 1990-2000* (in press); Canadian GDP: Statistics Canada, CANSIM II, Table 384-0002; US GHG: US EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000* (draft, February 2002); US GDP: BEA, 2000.

Table 1 Energy Production, Export and Greenhouse Gas Emission Trends, 1990 to 2000

Year	1990	2000	Change Since 1990 (%)
Greenhouse Gas Emissions[1] (Mt CO_2 eq)	607	726	19.6%
GDP[2] - Expense (Millions of 1997$)	764,386	1,012,809	32.5%
Domestic Energy Consumption[3] (PJ)	9,230	10,815	17%
Energy Production[3] (PJ)	7,752	11,729	51%
Energy Exported[3] (PJ)	3,049	7,044	131%
NET Energy Exported[3] (PJ)	1,755	4,822	175%
Emissions Associated with Exports[4] (Mt CO_2 eq)	28	65	134%
Emissions Associated with NET Exports[4] (Mt CO_2 eq)	22	48	121%

Sources:
[1] Environment Canada, Canada's Greenhouse Gas Inventory 1990-2000 (in press);
[2] Statistics Canada,CANSIM II, Table 384-0002;
[3] Statistics Canada, Catalogue # 57-003;
[4] For years 1990 to 1995, values were taken from McCann, T.J., et al. Fossil Fuel Energy Trade & Greenhouse Gas Emissions: A Quantitative Assessment of Emissions Related to Imports and Exports, Prepared for Environment Canada, 1997. Years 1996 to 2000 values were extrapolated from the report.

growth peaked at over 3.6% per year and fell consistently thereafter until 1999, when emissions rose 2.0% over the previous year (see text box). The increase in emissions during the past decade outpaced the 11% growth in population (Statistics Canada, #91-213), as well as an increase in total domestic energy consumption, which grew 17% (Statistics Canada, #57-003). Moreover, growth in total emissions was well short of the almost 33% increase in GDP between 1990 and 2000.

Figure 2 compares the trends in greenhouse gas emissions, GDP, and greenhouse gas intensity (a measure of the amount of greenhouse gases per unit of economic activity) for Canada and the United States between 1990 and 2000. Both countries experienced an improvement (meaning a reduction) in greenhouse gas intensity over the period. For example, Canada's greenhouse gas emissions per unit of GDP decreased by almost 10%, while the US experienced nearly a 17% reduction since 1990. It must be noted that a

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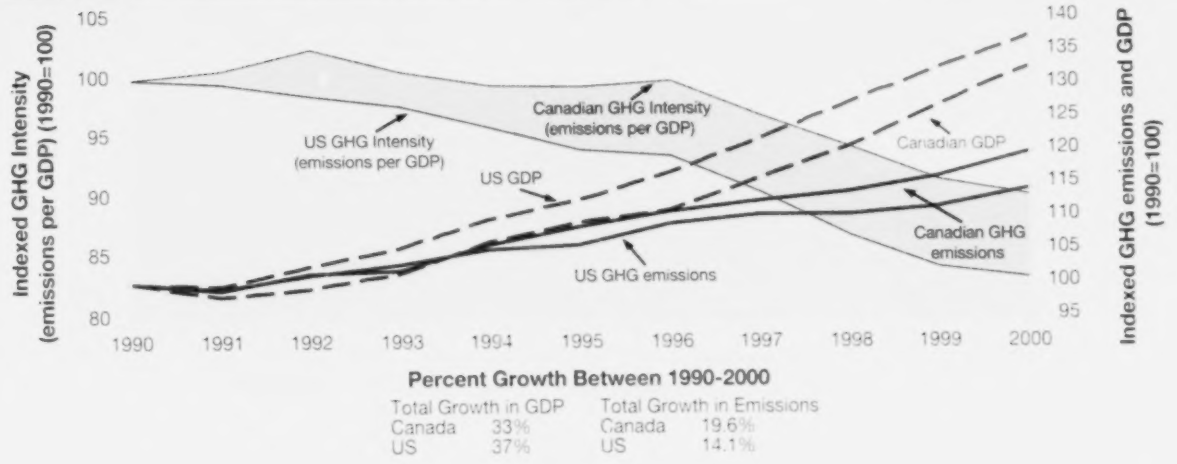

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Figure 2 compares the trends in greenhouse gas emissions, GDP, and greenhouse gas intensity (a measure of the amount of greenhouse gases per unit of economic activity) for Canada and the United States between 1990 and 2000. Both countries experienced an improvement (meaning a reduction) in greenhouse gas intensity over the period. For example, Canada's greenhouse gas emissions per unit of GDP decreased by almost 10%, while the US experienced nearly a 17% reduction since 1990. It must be noted that a

reduction in greenhouse gas intensity does not necessarily reflect a reduction in emissions; it can also indicate changes in the structure of the economy. A closer examination of the individual trends in emissions and GDP for the two countries reveals that Canada's emissions are growing faster while our GDP is growing slower than that of the US. Factors that affected Canadian emissions growth include increases in fossil fuel consumption for electricity generation, increased energy consumption in the transportation sector, and growth in fossil fuel production, largely for export.

In fact, growth in oil and gas exports, primarily to the United States, contributed significantly to emissions growth between 1990 and 2000 (Table 1). In this period, total energy production increased 51% and gross energy exported increased 131%, while emissions associated with those exports increased 134%. Emissions from all oil and gas production, processing and transmission activities that are attributable to gross exports accounted for over 30% of the total increase in Canada's greenhouse gas emissions over the period 1990-2000, increasing from 28 Mt in 1990 to 65 Mt in 2000.

Sector Trends in Canada's GHG Emissions and Removals: 1990 to 2000

Electricity and Petroleum Industries

- The Electricity and Petroleum Industries contributed 264 Mt, or 36% of total national emissions in 2000 (electricity-related emissions accounted for 48% and petroleum-related emissions 52% of the total emissions in this category).
- Since 1990, emissions grew almost 38%. On a sector basis, electricity generation increased 25% but emissions grew 35%, due to an increased proportion of fossil fuel-generated electricity in the latter 1990s.
- The Petroleum Industries' emissions increased 40% over the period, in which upstream emissions rose 54% while downstream emissions decreased 6%. The rise in Upstream Industry emissions is largely the result of increased production of oil and gas for export, whereas increased production efficiency in the refining of oil products contributed to the emissions decline in the Downstream Industry.

Table 2 Canada's Greenhouse Gas Emissions Summary by Sector, 1990 to 2000

GHG Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	Mt CO_2 equivalent										
Electricity and Petroleum Industries	193	194	208	203	209	220	223	230	249	256	264
Transportation	146	140	143	146	154	157	161	168	171	176	179
Industry*	117	115	113	113	118	119	124	123	114	112	119
Residential, Commercial and Institutional	70	69	71	74	74	74	79	76	68	72	77
Agriculture	59	58	58	58	60	61	61	61	61	61	60
Land-Use Change and Forestry (methane and nitrous oxide)	2	3	3	3	4	5	2	1	3	2	2
Waste	20	21	21	22	22	22	22	23	23	24	24
TOTAL	**607**	**600**	**616**	**619**	**641**	**658**	**672**	**682**	**689**	**703**	**726**

*Includes emissions from Solvents and Other Product Use.

Due to rounding, individual values may not add up to totals.

Transportation

- The Transportation sector represents one of the largest sources of emissions in Canada, accounting for 24.7% of total emissions in 2000 (179 Mt).
- Emissions increased 23% between 1990 and 2000. On-road transportation was the largest contributor to emissions in this sector, at 72.7%. Nearly all emissions growth can be attributed to Light-Duty Gasoline Trucks (LDGT, this includes sport utility vehicles and minivans), which contributed 44% or 14.7 Mt of this sector's growth and Heavy-duty Diesel Vehicles (HDDV), which accounted for 40% or 13.3 Mt of the growth.

Industry

- The Industry sector contributed 16% (118 Mt) of Canada's total emissions in 2000. Of these emissions, combustion emissions accounted for 59%, industrial process emissions 41% and fugitive emissions less than 1%.
- Key sub-sectors include the *Other Manufacturing and Industrial Chemicals Industries* (27% and 17% of total sector emissions, respectively), while *Smelting and Refining Industries and Primary and Other Steel Industries* combined accounted for a further 28%.
- Industry's emissions increased 1% between 1990 and 2000. The sector has stabilised its emissions despite an increase for most sub-sector industries in production and GDP. Emissions reductions occurred mainly as a result of a 8 Mt reduction in process emissions from adipic acid production improvements, as well as lowered GHG emission intensities through increased energy efficiency and fuel switching.

Residential, Commercial and Institutional (RCI) Sector

- RCI sector emissions in 2000 were 77 Mt and accounted for 10.6% of Canada's total emissions (45 Mt from the Residential sub-sector and 31.9 Mt from the Commercial and Institutional sub-sector).
- Overall, emissions grew 3% from 1990 to 2000, while on a sub-sector basis Residential emissions increased 2.3% and Commercial & Institutional emissions grew 23.4%. Changes in emissions resulted from an increase in energy use due to sub-sector growth. This was partially offset by energy efficiency improvements in building stock, warmer weather, and substitution of fuel oil by natural gas.

Agriculture

- In 2000, Agriculture greenhouse gas emissions totalled 60 Mt, and contributed 8.3% of the total national emissions. This sector accounted for 70% of Canada's total emissions of nitrous oxide and 25% of methane.
- On a category basis, agricultural soils contributed 55% of the sector's emissions (33.4 Mt) in 2000, enteric fermentation emissions from domestic animals 29% (17.7 Mt), and manure management 16% (9.4 Mt).
- While total sector emissions rose 3% between 1990 and 2000, emissions from manure management rose 13% and enteric fermentation emissions increased 11%. Net carbon dioxide emissions from agricultural soils partially offset these increases, changing from a net source of 7.3 Mt in 1990 to a net sink of 0.2 Mt in 2000. Nitrous oxide emissions from soils, however, rose 23% over the period.

Land-Use Change and Forestry (LUCF)

- The LUCF sector was a net sink in 2000, as it removed from the atmosphere an estimated 14 Mt. This estimate represents the sum of the net carbon dioxide flux and non-carbon dioxide (methane and nitrous oxide) emissions.
- The net carbon dioxide flux alone amounted to a sink (16 Mt); however, LUCF carbon dioxide fluxes are not included in the national inventory totals. If they were included, it would have resulted in a reduction of total Canadian emissions of 10% in 1990 and 2% in 2000. Non-carbon dioxide emissions, however, are included in the national totals and amounted to 2 Mt in 2000. Under the terms of the Kyoto Protocol, sources and sinks from some land-use change and forestry activities will be included and accounted for separately during the commitment period (2008-2012).
- Between 1990 and 2000, the LUCF sector overall remained a net sink but exhibited a 76% decline in the net removal over the period (from 59 Mt to 14 Mt).
- Overall, the trends observed in the LUCF category largely reflect the changing levels of industrial forestry activity during the 1990s.

Waste

- Waste sector emissions totalled 24 Mt, representing 3.3% of Canada's total emissions in 2000. The primary emissions source is solid waste disposal on land, which accounted for 93% of the sector's emissions. Ninety-five percent of the emissions (23 Mt) were methane.
- Since 1990, waste-related emissions rose by over 21%, of which 96% of the increase is attributable to a rise in landfill emissions. Although emissions from solid waste disposal on land rose nearly 22%, increased landfill gas capture reduced the rate of emissions growth from landfills in the early to middle 1990s.

Provincial and Territorial Greenhouse Gas Emissions

Table 3 provides a summary of greenhouse gas emissions by province and territory for 1990 and 2000 by sector (as defined by the UNFCCC). Although the UNFCCC Guidelines on annual inventories only require that national-level detail be reported, it is considered important to provide these details due to the distinct regional differences which exist within Canada. Also, it must be noted that provincial and territorial emission estimates do not sum exactly to the national totals. The differences are due to two factors - rounding and a suppression of confidential provincial activity data.

Table 3 Summary of Provincial and Territorial Greenhouse Gas Emissions by Sector, 1990 and 2000

	NF	PE	NS	NB	QC	ON	MB	SK	AB	BC	NT & NU	YT
1990 GHG Emissions by Sector						**kt CO2 equivalent**						
Energy	8,890	1,470	17,800	14,700	59,400	136,000	12,600	34,500	143,000	42,100	1,250	486
Industrial Processes	77	3	300	150	13,000	27,000	450	590	8,800	2,800	3	1
Solvent and Other Product Use	9	2	14	11	110	160	17	15	38	50	1	0
Agriculture	75	410	610	490	8,000	12,000	6,800	11,000	17,000	2,500	0	0
Land-Use Change and Forestry	30	1	40	20	200	200	40	100	100	2,000	6	10
Waste	360	77	590	500	5,800	7,200	420	500	1,000	3,600	14	7
Total	9,440	1,960	19,400	15,900	86,100	181,000	20,300	46,900	171,000	52,700	1,280	504
2000 GHG Emissions by Sector												
Energy	8,160	1,620	19,800	18,800	62,300	168,000	13,300	47,900	190,000	54,300	1,740	471
Industrial Processes	85	2	270	230	13,000	18,000	470	2,000	11,000	3,200	4	0
Solvent and Other Product Use	8	2	14	11	110	180	17	15	45	61	1	0
Agriculture	80	430	610	530	7,700	11,000	6,900	11,000	19,000	2,500	0	0
Land-Use Change and Forestry	40	3	50	50	400	400	100	200	300	800	60	50
Waste	430	91	700	600	6,700	8,300	600	610	1,200	5,000	19	8
Total	8,810	2,150	21,500	20,200	90,400	207,000	21,400	61,800	223,000	65,900	1,830	529
Change since 1990												
kilo tonnes	-630	190	2,100	4,300	4,300	26,000	1,100	14,900	52,000	13,200	550	25
%	-7%	10%	11%	27%	5%	14%	5%	32%	30%	25%	43%	5%
2000 GHG per capita[1]* (tonnes GHG/person) (National average - 23.6 tonnes/person)	16.4	15.5	22.8	26.7	12.3	17.7	18.6	60.4	74.4	16.2	26.2	17.3
2000 GHG Intensity of GDP[2] (GHG kt CO_2 eq/$GDP) (National value - 0.72)	0.69	0.68	0.94	1.09	0.42	0.49	0.65	1.97	1.85	0.53	0.58	0.49

Due to rounding, individual values may not add up to totals (zero values may represent estimated quantities too small to display). Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national total.

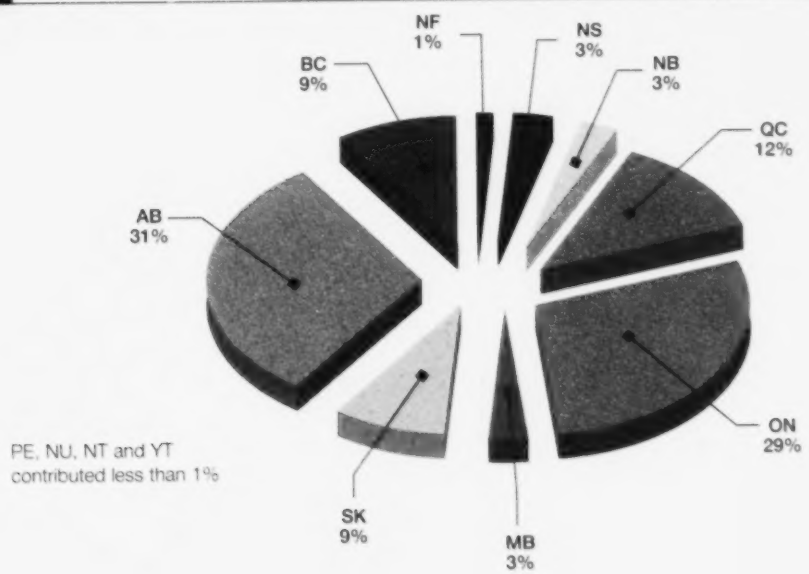
Source: Emissions data from Environment Canada, Canada's Greenhouse Gas Inventory 1990-2000 (in press); [1]Population data from Statistics Canada, 2000, Catalogue #91-213; [2]GDP data from Statistics Canada, CANSIM II, Table 384-0002.

Greenhouse gas emissions across Canada are not distributed evenly. Regional differences in factors such as climate, resources available for energy production and/or industry, as well as travel patterns, all contribute to different patterns of emissions. Figure 3 illustrates the provincial and territorial contributions to Canada's total emissions in 2000. The largest provincial contributors were Alberta with 31% of Canada's total emissions (223 Mt), and Ontario, which accounted for 29% of the national total (207 Mt). The next largest contribution to national emissions was from Quebec, at 12%, while British Columbia and Saskatchewan each contributed 9%. The remainder of the emissions in 2000 were from Manitoba, Nova Scotia and New Brunswick (each accounting for about 3%), Newfoundland and Labrador added 1%, while Prince Edward Island and the territories together contributed less than 1% to the total national emissions in 2000.

In terms of emissions growth, all provinces and territories except Newfoundland and Labrador experienced an increase in their emissions over the 1990 to 2000 period. Emissions from Saskatchewan rose 32%, while Alberta, British Columbia and New Brunswick exhibited increases ranging between 25% and 30%. In addition, during this ten year period four provinces were responsible for almost 90% of the **total national growth** in emissions - Alberta accounted for 44% of the total growth, while Ontario and Saskatchewan contributed 22% and 13%, respectively, and British Columbia added 11%.

An in-depth breakdown of provincial and territorial greenhouse gas emissions is beyond the scope of this fact sheet; however, for a complete summary of provincial and territorial emissions for the years 1990 through 2000 inclusive, consult Environment Canada's *Greenhouse Gas Emissions* web site at http://www.ec.gc.ca/pdb/ghg/

Figure 3 Provincial and Territorial Contributions to Canada's Greenhouse Gas Emissions in 2000



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CANADA'S GREENHOUSE GAS INVENTORY
GHG Trends Information from Environment Canada's Greenhouse Gas Division

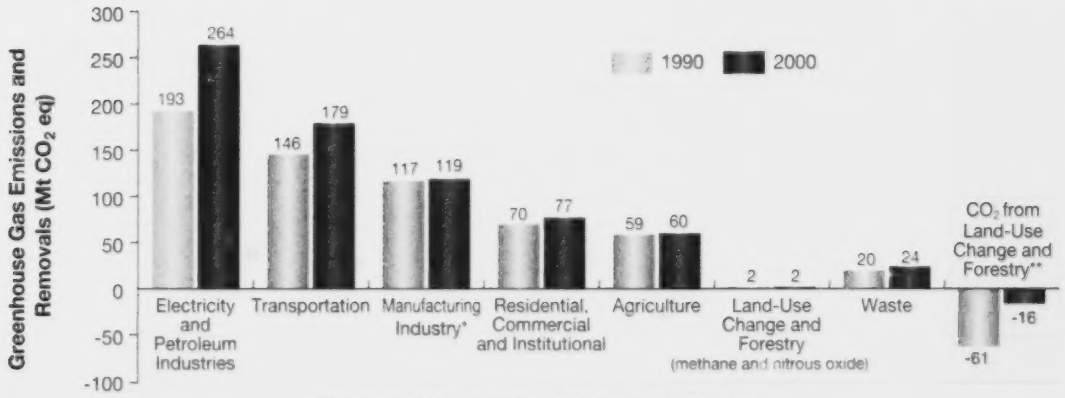
Electricity and Petroleum Industries: 1990-2000

The Electricity and Petroleum Industries Fact Sheet is comprised of two sectors: the Electricity Generation sector and the Petroleum Industry sector. The Petroleum sector includes emissions from both the upstream and downstream petroleum industries. The Electricity Generation sector consists of combustion emissions associated with electricity generation and steam production for mainly residential, commercial and manufacturing use.

- *In 2000*, Electricity and Petroleum Industries contributed 36% or 264 megatonnes of carbon dioxide equivalent* (Mt CO_2 eq) of Canada's total greenhouse gas emissions of 726 Mt. Both the petroleum and electricity production contributed 136 Mt and 128 Mt of emissions, respectively. On a sub-sector basis, upstream petroleum emissions accounted for the majority of the Petroleum Industry sector emissions (113 Mt, or 85% of the sector total), while downstream petroleum contributed 21 Mt.
- *Between 1990 and 2000*, emissions within the Electricity and Petroleum Industries grew by almost 37%, from 193 Mt to 264 Mt, surpassing the growth rate of total national emissions of 20%. On a sector basis, although electricity generation increased 25%, emissions in this sector grew 35%, due to an increased proportion of fossil fuel-generated electricity in the latter part of the decade. Although the Petroleum Industry sector emissions increased 39% over the period, on a sub-sector level upstream emissions rose 54% while downstream emissions decreased 5.5%. Upstream Industry emissions rose primarily as a result of increased production of oil and gas for export, whereas increased production efficiency in the refining of oil products contributed to the emissions decline in the Downstream Industry.

*Unless otherwise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a relative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.

Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000



*Value illustrated includes emissions due to Solvent and Other Product Use.
**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals.

Canada's Electricity and Petroleum Industries Sector

The Electricity and Petroleum Industries are comprised of two important energy sectors - the Electricity Generation and Petroleum Industries sectors. The Petroleum Industries sector can be further subdivided into two categories: the Upstream Petroleum Industry and the Downstream Petroleum Industry.

Emissions from the Upstream Petroleum Industry are those associated with oil and natural gas exploration, production and transmission, and include (Table 1):

- *fugitive* emissions (such as flaring, raw CO_2 releases, vent blows, gas migrations etc.) during exploration, production and transport; responsible in 2000 for 44% of Upstream Industry emissions;
- *process* emissions from the extraction of hydrogen from natural gas (used in heavy oil upgrading); responsible in 2000 for only 2.1% of Upstream Industry emissions; and
- *combustion* emissions from the exploration and extraction of oil and gas, the upgrading of oilsands, as well as the transmission of natural gas; responsible in 2000 for 54% of Upstream Industry emissions.

The Downstream Petroleum Industry includes the refining of crude oil and the distribution of natural gas. Emission sources consist of (Table 1):

- *fugitive* natural gas emissions from gas distribution; responsible in 2000 for 15% of downstream emissions;
- *process* emissions from the extraction of hydrogen from natural gas used in refining processes; responsible in 2000 for 4.6% of downstream emissions; and
- *combustion* emissions during refining of the industry's produced petroleum products (such as motor gasoline, diesel, and aviation fuel); responsible in 2000 for 80% of downstream emissions.

The Canadian Greenhouse Gas Inventory (CGHGI)

The Canadian Greenhouse Gas Inventory is developed, compiled, and reported annually by the Greenhouse Gas Division of Environment Canada, and utilizes methods and models developed in-house by engineering and scientific staff, as well as published data, data developed by industry, or methods developed by the Intergovernmental Panel on Climate Change (IPCC, 1997).

The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).

The inventory uses an internationally agreed to reporting format that groups emissions and removals into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry, and Waste. The 2000 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, uses a modified sector approach to facilitate the use of information by the public.

Table 1 Electricity and Petroleum Industries' Greenhouse Gas Emissions, 2000, Mt CO_2 eq

Sector	Fuel Combustion	Industrial Process	Fugitive
Electricity Generation[1]	128		
Petroleum Industry	79.5	3.4	53.1
Upstream Petroleum Industry[4]	61.7	2.3	49.8
Upstream Oil and Gas[2]	50.4	2.3	44.2
Natural Gas Transmission	11.3		5.6
Downstream Petroleum Industry	17.8	1.0	3.3
Petroleum Refining[3]	17.8	1.0	
Natural Gas Distribution			3.3

Notes: Due to rounding, individual values may not add up to totals.

[1] Includes both utility & industrial generation and commercial steam generation.

[2] Includes combustion, process and fugitive emissions associated with conventional and unconventional production of oil and gas.

[3] Includes combustion and process emissions associated with the refining of crude oil.

[4] A small proportion of emissions from the Upstream Petroleum Industry is accounted for in the Mining sector due to data limitations.

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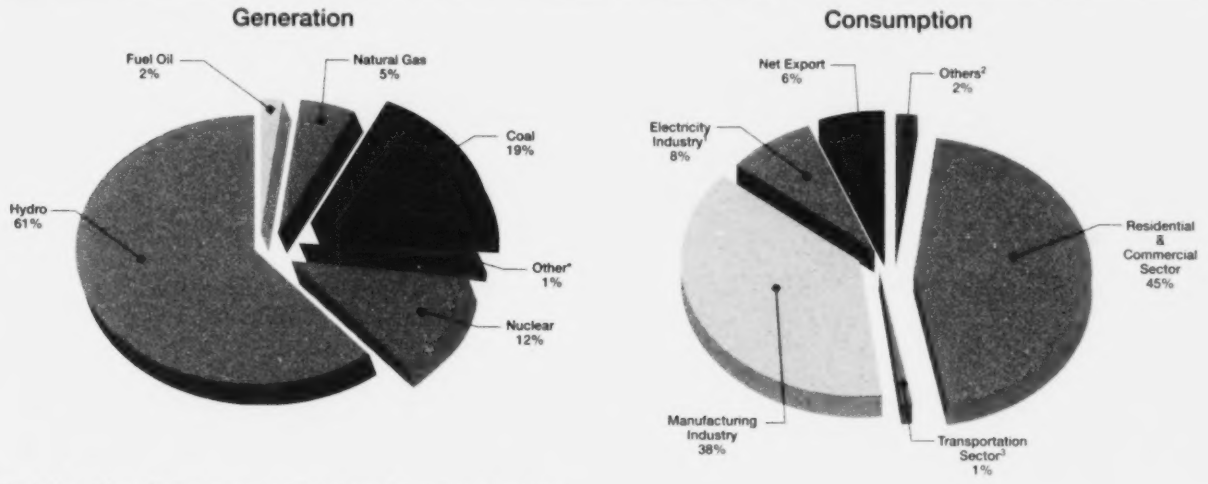
Figure 2 2000 Electricity Generation and Consumption Sources in Canada



*Includes – Use of wood waste, spent pulping liquor and other fuels
[1] Includes - Electricity industry's own consumption and transmission losses
[2] Includes - Agricultural sector's electricity consumption
[3] Includes - Pipelines, urban transit and street lighting
Data Source: Statistics Canada, Electric Power Generation, Transmission and Distribution, Catalogue 57-202, 2000

The Electricity Generation sector includes greenhouse gas emissions from thermal generation in Canada, whether from a utility or from industry. Only a portion of Canada's generation is responsible for greenhouse gas emissions. In 2000, about 28% of the total 586 TWh generated electricity was from greenhouse gas emitting thermal generation sources (fossil fuels). The remainder was from non-emitting sources such as hydro and nuclear, with a minor portion from biomass and wind (Figure 2). The manufacturing, residential and commercial sector together consumed nearly 83% of available electricity in 2000. Main uses of electricity in the residential and commercial sectors are for lighting, appliances, electronic devices, water heating and space heating and cooling. The Smelting, Refining and the Pulp and Paper industries are also some of the large primary electricity consumers within the manufacturing industries.

Electricity and Petroleum Industries Emission Trends: 1990 to 2000

Emissions within the Electricity and Petroleum Industries have grown significantly in the 1990 to 2000 period. While total Canadian emissions grew by almost 20%, those from the Electricity and Petroleum Industries sector grew by almost 37%, from 193 Mt to 264 Mt. Emission growth occurred mainly in the Upstream Petroleum Industry and the Electricity Generation sector by 54% and 35%, respectively. (Table 2).

Several factors can influence the growth or decline of emissions:

- Energy Demand (domestic and foreign demands)
- Energy Production Efficiency Improvements
- Fuel Switching

Table 2 Greenhouse Gas Emission Trends in the Electricity and Petroleum Industries, 1990 to 2000, Mt CO_2 eq

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
ELECTRICITY GENERATION[1]	95.3	96.7	103	93.8	96.0	101	100	111	124	121	128
PETROLEUM INDUSTRY	97.5	97.8	106	109	113	119	123	119	125	135	136
Upstream Petroleum Industry[4]	74.1	75.4	82.9	86.3	90.9	97.4	100	97.1	103	113	114
Upstream Oil and Gas[2]	62.9	63.4	68.3	71.2	75.1	80.2	82.3	79.3	85.2	95.5	97.0
Natural Gas Transmission	11.2	12.1	14.6	15.2	15.8	17.1	17.7	17.8	17.8	17.9	16.8
Downstream Petroleum Industry	23.4	22.3	22.6	22.9	21.9	21.9	23.2	21.9	22.0	21.3	22.1
Petroleum Refining[3]	20.7	19.5	19.7	20.1	19.0	18.9	20.2	18.8	18.8	18.1	18.8
Natural Gas Distribution	2.8	2.8	2.9	2.8	3.0	3.0	3.0	3.1	3.2	3.2	3.3

Notes: Due to rounding, individual values may not add up to totals.

[1] Includes both utility & industrial generation and commercial steam generation.

[2] Includes combustion, process and fugitive emissions associated with conventional and unconventional production of oil and gas

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[4] A small proportion of emissions from the Upstream Petroleum Industry is accounted for in the Mining sector due to data limitations.

The Petroleum Industries Sector

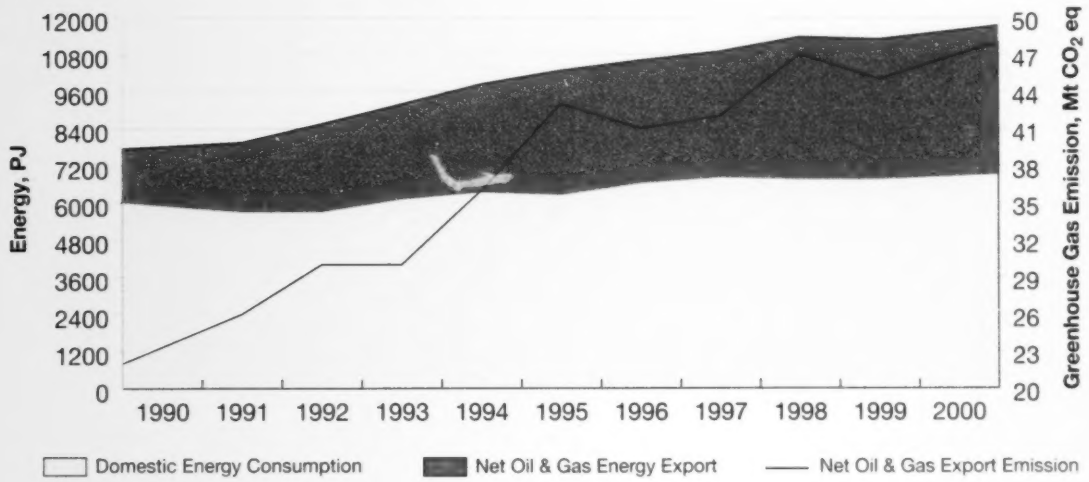
Emissions from the Upstream Petroleum Industry have experienced high growth over the period 1990-2000. Since 1990, upstream petroleum emissions have increased by 54%. In 2000 nearly 85% of these emissions were created in the extraction and product conditioning of crude oil, oil sands and natural gas, through either combustion for mining/extraction or fugitive emissions at the source of production.

The growth of greenhouse gas emissions can therefore be directly attributed to increased production of oil and gas. Growth in oil and gas exports, primarily to the United States, contributed significantly to emissions growth between 1990 and 2000 (Figure 3). In this period, net oil exports grew by 328% to 1037 PJ, while net exports of gas increased 150% to 3785 PJ. As natural gas exports increased, so did transmission networks, such that emissions increased by nearly 80% from pipeline compressors and other equipment, as well as fugitive emissions from leaks. The proportion of emissions from all oil and gas production and processing activities that is attributable to exports increased from 22 Mt in 1990 to 48 Mt in 2000. Overall, total oil and gas energy exported increased 175% between 1990 and 2000, while emissions associated with oil and gas exports increased 121%.

As production increases, efficiency improvements are contributing to emission reductions in the Upstream Petroleum Industry. By 1997, oil sands produced 45% less emissions per unit production over 1990. On the other hand, ageing conventional crude reserves are offsetting the upstream petroleum industries' efficiency improvements, due to increased pumping for deposits and disposing of increasing amounts of water (Athabasca, 2000). Unfortunately, data are not readily available to support detailed analysis of efficiency changes in the sub-sector.

Emissions from the Downstream Petroleum Industry show an opposite trend to that of emissions in the Upstream sector, having decreased 5.5% since 1990. These emission reductions occurred even though the sub-sector experienced increases in production. 85% of downstream emissions, are due to the refining of crude oil while fugitive emissions from gas distribution contribute the remainder. Refinery

Figure 3 1990 to 2000 Domestic Energy Consumption, Net Energy Export and Emission Trends



production has increased by 11% over 1990 levels. The overall reduction in emissions can be attributed to the increasing production efficiency in refining. The energy requirements per unit of output dropped dramatically (9%) over the 1990 to 2000 period (CIEEDAC, 2001).

Electricity Generation Sector

Regionally in Canada, five provinces (Alberta, Ontario, Saskatchewan, New Brunswick and Nova Scotia) together contribute nearly all of the electricity generation emissions, largely because of their reliance on coal or other fossil fuels to generate electricity (Figure 4). Of these, Ontario and Alberta contributed over 71% in 2000. On the other hand, Ontario only generated 26% and Alberta 10% of total Canadian electricity in that year.

Emission trends for electricity generation have been generally upward since 1990. The growth of emissions is influenced by the growth in electricity demand and hence generation. By 2000, electricity generation from all sources had grown 25%. At the same time greenhouse gas emissions were 35% higher. The widening gap between growth in emissions and generation may be explained by the growing "emission intensity" of Canadian generation sources. This intensity, or the mass of CO_2 eq/kWh generated, is dependant on the proportion of fossil fuel-generated electricity in the overall mix. As fossil fuels play a proportionally larger role in generating power, greenhouse gas emissions tend to rise proportionally, as well. For example, in 2000 fossil fuels contributed about 28% more to the total generation mix than they did in 1990. As a result, the greenhouse gas intensity was about 7.5% higher. Although changes in the overall emission intensity and in the proportion of fossil fuel generation to the total tend to mirror each other (Table 3), the increased use of natural gas combined with the decreased use of highly carbon intensive fuels such as coal and fuel oil has resulted in a 13% decrease in fossil fuel generated emission intensity.

As discussed earlier, Alberta and Ontario, contributed the majority of emissions in 2000 because of their relatively large generation capacities and high proportions of fossil fuel generation (Figure 4). Because of their influence on Canada-wide emission intensity trends, it is instructive to take a detailed look at these provinces.

Figure 4 Electricity Generation and Greenhouse Gas Emissions by Province, 2000

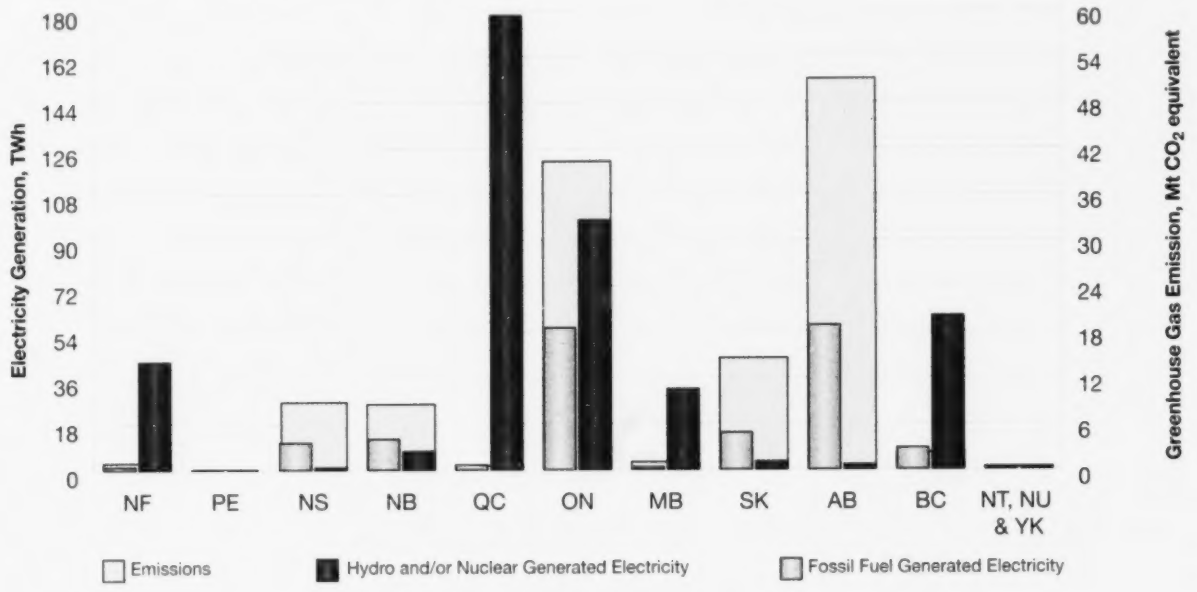
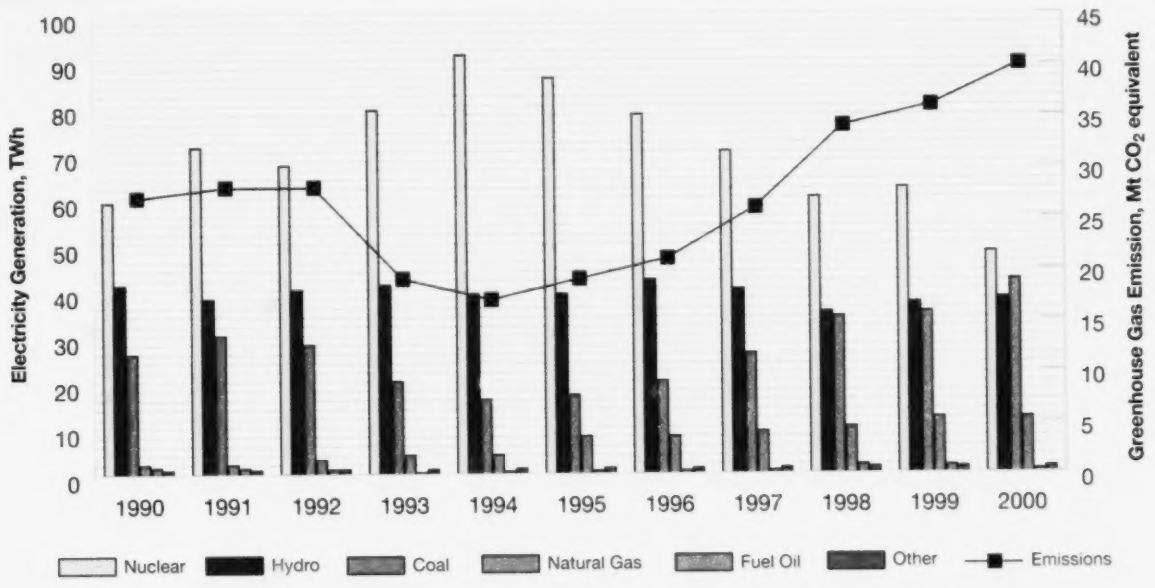


Table 3 Trends in Electricity Emissions and Energy Used, 1990 to 2000

	Overall Emission Intensity	Overall Electricity Generation by Sources			Fossil Fuel Generated	Fossil Fuel Generated Electricity				
		Fossil Fuel	Hydro	Nuclear	Emission Intensity	Total	Percent Contribution			
							Coal	Natural Gas	Fuel Oil	Other[1]
	kt CO_2 equivalent/ TWh	% Contribution			kt CO_2 equivalent/ TWh	TWh	%			
1990	204	22	63	15	909	105	73	9	14	4
1991	196	22	62	16	899	108	77	7	11	4
1992	204	23	62	15	894	115	73	11	12	5
1993	182	21	62	17	877	107	72	13	9	5
1994	178	21	61	19	864	111	73	14	7	6
1995	186	22	61	17	858	118	69	17	8	6
1996	179	21	63	16	859	116	72	15	7	6
1997	200	24	62	14	851	131	71	15	9	5
1998	227	27	60	12	837	148	68	17	11	5
1999	217	27	61	12	818	148	68	17	9	6
2000	219	28	61	12	791	162	68	19	8	5

[1] Includes wood & spent pulping liquor, manufactured gases, other petroleum products, other fuels and station service
Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

Figure 5 Ontario Electricity Trends: Generation by Sources and Greenhouse Gas Emissions, 1990 to 2000



Other: Includes wood waste, spent pulping liquor and other fuel use to generate electricity
Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

Ontario

Ontario's generation capacity is made up of hydroelectric, nuclear, coal, oil and gas. In 1990 non-greenhouse gas emitting generation contributed 78% of the electric energy. Until 1994 this portion grew larger as nuclear and hydro contributed a greater share. In the mid 1990s, nuclear facilities suffered reduced capacity for maintenance purposes; as a result, these losses were made up for by unused fossil-fuel thermal capacity (Figure 5).

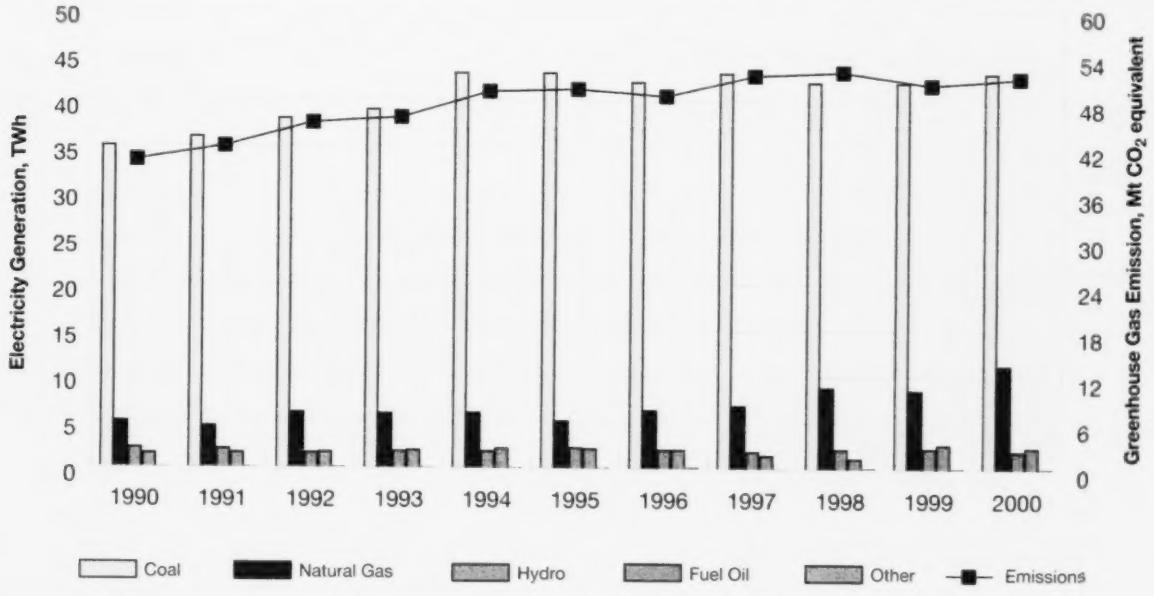
The trend over this period is clear. Generation output grew to the middle 1990s and then levelled off with the recession. Changes to emissions followed closely to the proportion of fossil fuel generation sources, such as coal and natural gas.

Alberta

Alberta's generation capacity is comprised primarily of fossil fuel generation: coal and natural gas. Together these fuels produced about 95% of all electricity in the province over the last decade. In the mid 90's natural gas began replacing coal, such that this fuel's share of generation was reduced from 82% to 74%.

There are clear trends over the 1990 to 2000 period. Total generation increased by about 35% and, because of the dependence on fossil fuel generation, total emissions also increased by 27%. As natural gas replaced a portion of coal, emission intensities were lowered in the latter part of the decade. Emission intensity decreased by 6% in 2000 (Figure 6).

Figure 6 Alberta Electricity Trends: Generation by Sources and Emissions, 1990 to 2000



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CANADA'S GREENHOUSE GAS INVENTORY

GHG Trends Information from Environment Canada's Greenhouse Gas Division

Transportation: 1990-2000

The Transportation sector includes estimates of all human induced greenhouse gases (GHG) resulting from the consumption of fossil fuels to move passengers, freight and bulk commodities throughout Canada. This category may be broken into five distinct sub-categories: on-road, air, marine, rail, and off-road. Emissions of carbon dioxide (CO_2: 94.7%) dominate this sector, although combustion processes also generate nitrous oxide (N_2O: 5.1%) and methane (CH_4: 0.3%).

- *In 2000,* the Transportation sector accounted for 179 megatonnes of carbon dioxide equivalent* (Mt CO_2 eq) emissions. This sector represents one of the largest sources of emissions, and was responsible for 24.7% of Canada's total emissions of 726 Mt.
- *Between 1990 and 2000,* this sector contributed 27.9% to Canada's emissions growth of 119 Mt. In 1990, Transportation is estimated to have emitted 146 Mt; in 2000, this had risen 22.7%. Almost all of the growth in emissions since 1990 can be attributed to 3 sub-sectors. Light-Duty Gasoline Trucks (LDGT), the category including Sport Utility Vehicles (SUVs) and Minivans, contributed 44.2% or 14.7 Mt of this sector's growth, Heavy-duty Diesel Vehicles (HDDV) contributed 40.1% or 13.3 Mt and Off-Road Diesel Vehicles were responsible for 20.6% or 6.8 Mt of the overall sectoral growth. Offsetting this growth has been the continued steady decline of emissions from Light Duty Gasoline Vehicles (LDGV a.k.a. "Cars") equal to –16.3% or –5.4 Mt of the same total.

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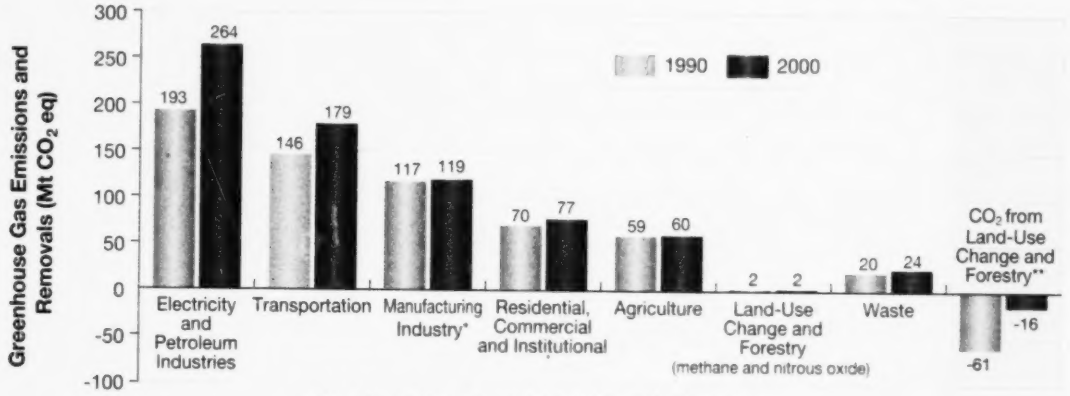

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**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals.

Table 1 Canadian Transportation GHG Emissions by Sub-Sector 1990 to 2000

Vehicular Transportation Total	GHG Emissions (Mt)		Change 1990-2000		Contribution to 2000 Total	Contribution to 1990-2000 Growth	Functional Subcategories			
	1990	2000	(Mt)	(%)			On-Road	Off-Road	Passenger	Freight
Light-Duty Gas Vehicles (cars)	53.7	48.3	-5.4	-10.1%	27%	-16%	•		•	
Light-Duty Gas Trucks	21.7	36.4	14.7	67.5%	20%	44%	•		•	
Heavy-Duty Gas Vehicles	3.1	5.8	2.7	86.5%	3%	8%	•			•
Motorcycles	0.2	0.2	0.0	4.0%	0%	0%	•		•	
Off-Road Gas Vehicles	5.0	5.3	0.3	5.2%	3%	1%		•		•
Light-Duty Diesel Vehicles (cars)	0.7	0.4	-0.3	-39.0%	0%	-1%	•		•	
Light-Duty Diesel Trucks	0.6	0.1	-0.5	-77.0%	0%	-1%	•			•
Heavy-Duty Diesel Trucks	24.6	37.8	13.3	54.2%	21%	40%	•			•
Off-Road Diesel Vehicles	11.3	18.1	6.8	60.6%	10%	21%		•		•
Propane and Natural Gas Vehicles	2.2	1.1	-1.1	-50.0%	1%	-3%	•			•
Domestic Air	10.7	13.7	3.0	28.1%	8%	9%			81%	19%
Domestic Marine	5.0	5.1	0.1	1.2%	3%	0%			0%	100%
Rail	7.1	6.7	-0.4	-6.2%	4%	-1%			3%	97%
Vehicles Subtotal	**146**	**179**	**33.2**	**22.7%**	**100%**	**100%**				

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Canada's Transportation Sector

In Canada, transportation activities involve over 17 million On-Road vehicles alone. This sector also includes the largest of sea going vessels to the smallest gas powered lawn trimmer. It includes a variety of vehicle types, using various fuels with properties that constantly change depending on the season, geographic location or specific vehicle configuration. Furthermore, individual vehicles operating under different conditions greatly affect the rate at which they generate emissions. As a consequence, developing estimates of greenhouse gas emissions within this diverse sector is complicated at best. Methods rely on a combination of practices incorporating internationally accepted estimation protocols and measured emission data derived from emission testing undertaken in the United States and Canada. A complete description of the methods and principles used to generate the estimates are described elsewhere (Environment Canada, 2002).

Under the United Nations Framework Convention on Climate Change (UNFCCC) guidelines and the

Table 1 Canadian Transportation GHG Emissions by Sub-Sector 1990 to 2000

Vehicular Transportation Total	GHG Emissions (Mt)		Change 1990-2000		Contribution to 2000 Total	Contribution to 1990-2000 Growth	Functional Subcategories			
	1990	2000	(Mt)	(%)			On-Road	Off-Road	Passenger	Freight
Light-Duty Gas Vehicles (cars)	53.7	48.3	-5.4	-10.1%	27%	-16%	*		*	
Light-Duty Gas Trucks	21.7	36.4	14.7	67.5%	20%	44%	*		*	
Heavy-Duty Gas Vehicles	3.1	5.8	2.7	86.5%	3%	8%	*			*
Motorcycles	0.2	0.2	0.0	4.0%	0%	0%	*		*	
Off-Road Gas Vehicles	5.0	5.3	0.3	5.2%	3%	1%		*		*
Light-Duty Diesel Vehicles (cars)	0.7	0.4	-0.3	-39.0%	0%	-1%	*		*	
Light-Duty Diesel Trucks	0.6	0.1	-0.5	-77.0%	0%	-1%	*			*
Heavy-Duty Diesel Trucks	24.6	37.8	13.3	54.2%	21%	40%	*			*
Off-Road Diesel Vehicles	11.3	18.1	6.8	60.6%	10%	21%		*		*
Propane and Natural Gas Vehicles	2.2	1.1	-1.1	-50.0%	1%	-3%	*			*
Domestic Air	10.7	13.7	3.0	28.1%	8%	9%			81%	19%
Domestic Marine	5.0	5.1	0.1	1.2%	3%	0%			0%	100%
Rail	7.1	6.7	-0.4	-6.2%	4%	-1%			3%	97%
Vehicles Subtotal	**146**	**179**	**33.2**	**22.7%**	**100%**	**100%**				

The Canadian Greenhouse Gas Inventory (CGHGI)

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Under the United Nations Framework Convention on Climate Change (UNFCCC) guidelines and the

international reporting protocol, pipeline emissions are reported within the Transportation sector (IPCC, 1997). These emissions are typically compressor emissions and fugitive leaks resulting from the bulk transport of fuels in oil and/or natural gas pipelines.

Pipeline emissions are the only non-vehicular transport mode and for the purposes of this Fact Sheet Series, these emissions and their trends are reported within the Oil and Gas industry (see Fact Sheet #2 - Electricity and Petroleum Industries: 1990-2000).

General Trends

Vehicular Transportation emissions, henceforth referred to collectively as Transportation, increased 22.7% from 146 to 179 Mt over the period 1990-2000. Of the 33.2 Mt increase in emissions, 10.6 Mt can be attributed to passenger use, while 22.5 Mt may be attributed to freight purposes.

In order to distinguish trends in the use of vehicles as well as by type of vehicle, the following trend analysis has been undertaken and presented by both Form and Function. That is, what are the trends when observed according to the different types of transport vehicles - described by their Form, and what are the trends when we consider how we use these vehicles, distinguished by their Function, for either passenger or freight purposes. Furthermore, most transport modes include a component of both passenger and freight but for the purposes of the trend evaluations, Marine and Off-Road are assumed to be predominantly non-passenger and, therefore, their emissions are allocated to Freight.

Trends in Transportation Emissions by Vehicle Type (Form)

In Canada, Transportation can be divided into 5 distinct sub-sectors:

- Domestic Air (80% Passenger);
- Rail (3% Passenger);
- Domestic Marine (0% Passenger);
- Off-Road (0% Passenger); and
- On-Road (67% Passenger).

Domestic Air

Air transport in Canada includes both domestic and international flights. For accounting purposes, only those fuels sold to Canadian registered carriers in Canada are reported within the inventory. This principle complies with the established international guidelines governing bunker fuels.

Emissions associated with Domestic Air transportation increased 28.1% while through the same period their total activity, measured in total tonne-kilometres shipped, increased 52.5% and contributed to a 16.0% reduction in GHG intensity.

Rail

Rail transport boasts the lowest GHG intensity of all the freight modes. Total emissions actually declined 6.2% since 1990 while their annual shipping activity increased 35.9% over the same period, further reducing (improving) their GHG shipping intensity by 31%.

Domestic Marine

Marine Transport, like Air, has a substantial international component and similarly only the emissions resulting from fuel sold in Canada to Canadian registered vessels are considered here.

Although this sector's emissions have fluctuated over the period, overall emissions rose by only 1.2% from 1990 to 2000. Their activity, however, based on tonne-kilometres shipped, shows a reduction of almost 27.5%. While the GHG intensity associated with Domestic Marine is second only to that of Rail, these diverging factors illustrate an increase in GHG shipping intensity of 39.6%.

Off-Road

This sector, sometimes referred to as "Non-Road", includes the use of heavy mobile equipment in the construction, mining, and logging sectors, recreational vehicles such as snowmobiles, and lawn and garden devices including lawnmowers and trimmers. The estimates are calculated using data on volumes of fuel sold that are reported as being exclusive of road tax.

In 2000, the Off-Road sector contributed an estimated 23.4 Mt or 3.2% of the national total, up from 16.3 Mt in 1990. Although this sector includes both gasoline powered equipment (snowmobiles, all-terrain vehicles, etc.) and diesel powered equipment (excavating, construction, generator sets, etc.), 96.3% of the period's growth resulted from the 60.6% increase in the diesel component (11.3 to 18.1 Mt). Emissions from Off-Road gasoline sources rose 5.2% from 5.0 to 5.3 Mt.

On-Road

With greenhouse gas emissions of 130.3 Mt in 2000, this category contributed 17.9% of Canada's total emissions and 72.7% of the total emissions from transportation.

For the purposes of calculating estimates, the entire On-Road component is divided into 8 categories:

- Light-Duty Gasoline Vehicles (LDGV);
- Light-Duty Diesel Vehicles (LDDV);
- Light-Duty Gasoline Trucks (LDGT);
- Light-Duty Diesel Trucks (LDDT);
- Heavy-duty Gasoline Vehicles (HDGV);
- Heavy-duty Diesel Vehicles (HDDV);
- Motorcycles (MC); and
- Alternative Fueled Vehicles (Alt Fuel).

Factors influencing the quantity of greenhouse gases produced and emitted are mainly dependent upon:

- vehicle population;
- vehicle kilometres traveled (Vkmt);
- fuel consumption ratio (FCR), and
- emission control technology.

Since 1990, each of the 8 sub-categories has experienced changes in the above factors; yet these factors, sometimes moving in opposite directions for different vehicle sub-categories, indicate shifts in preference and utility for the Canadian vehicle operator (Table 2).

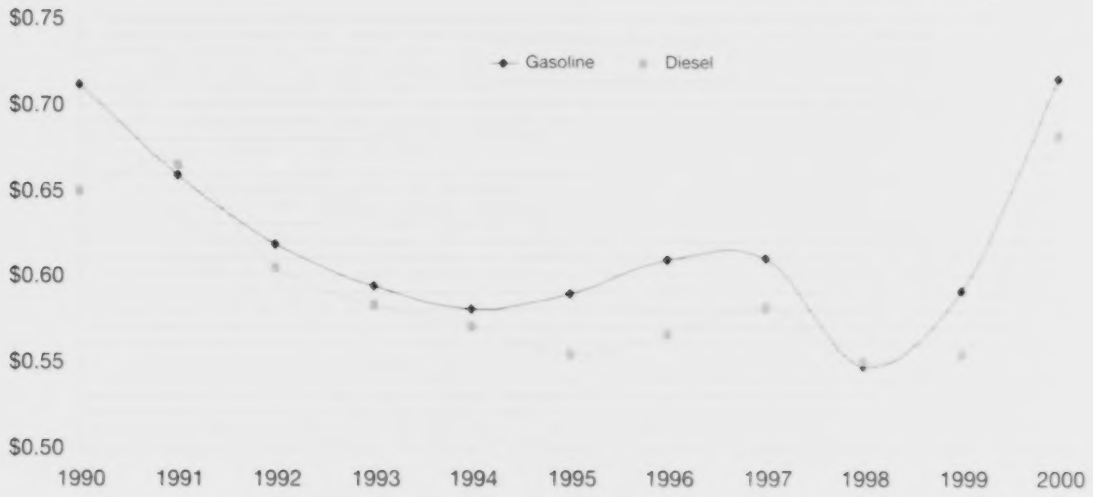
From 1990-2000, Gross Domestic Product (GDP) and population grew 32.5% and 11.0%, respectively, while the total number of On-Road vehicles increased 15.3%. Most of the vehicle population increase has occurred in the light-duty gasoline truck, heavy-duty gasoline and heavy-duty diesel truck categories, which have shown individual growth rates over the period of 68.7%, 75.3%, and 126.5%, respectively. Evidence of a shift towards bigger, less efficient (more GHG intense) vehicles is indicated when one considers that the number of light-duty gasoline cars has declined 4.3% while the number of light-duty diesel vehicles (including cars and trucks) has decreased 52.9%. One contributing factor is likely to be the almost steady decline in the real price of fuel through most of the 90's (Figure 2).

With the exception of LDDT and HDDV, each showing vehicle-kilometres-traveled declines of about 30% since 1990, vehicle kilometres traveled in all other categories show growth of about 4-7% from 1990 to 2000.

Table 2 Factors Contributing to Trends in Emissions Between 1990 and 2000

	Vehicle Population	FCR	Vehicle km Travelled	Combined Effect	Change Since 1990	
					Kt	%
LDGV	-4%	-12%	6%	-11%	-5,399	-10%
LDGT	69%	-9%	7%	65%	14,666	67%
HDGV	75%	0%	6%	86%	2,712	87%
MC	-1%	0%	6%	4%	9	4%
LDDV	-42%	0%	4%	-39%	-262	-39%
LDDT	-72%	0%	-18%	-77%	-455	-77%
HDDV	127%	0%	-32%	54%	13,295	54%

Figure 2 Trends in Canadian Fuel Prices (2000$)



Over 90% of Canada's fleet of vehicles has benefited from improved efficiencies over the ten-year period. Since the 1990 model year, the LDGV component of the fleet has become 12% more fuel-efficient while the similar LDGT component improved 9%.

Improvements in the emission control technology incorporated into new vehicles have been less progressive through the 1990's. The largest gains in emission reductions through technological improvements occurred in the 1980's when computer control, electronic fuel injection and new generation catalytic converters were introduced. As these technologies penetrate the market place, and as older vehicles are retired and replaced with vehicles incorporating more advanced emission and engine control devices, the benefits of these advances are realized.

Trends in Transportation Emissions by Vehicle Use (Function)

Passenger Transportation

This functional category encompasses those greenhouse gas emissions from mobile sources primarily used for the movement of people. In 2000, 97.9 Mt or 54.6% of total vehicular emissions were allocated to this category, a rise from 87.2 Mt or 59.8% of the same total in 1990. On a national basis, 13.4% of Canada's total emissions are allocated here with 98.0% coming from LDGV, LDGT and the passenger portion of Domestic Air travel (49.3%, 37.2% and 11.5%, respectively).

While emissions from the passenger portion of Domestic Air travel increased 32.2% and those from LDGV have actually decreased 10.1%, the overall trend has been heavily influenced by an almost 67.5% increase in emissions from LDGT, the class of vehicle that includes Sport Utility Vehicles (SUVs) and Mini-Vans.

Freight Transportation

In 2000, the collection of sub-categories representing freight and bulk transport contributed 81.2 Mt or 11.2% of Canada's total greenhouse gas emissions, an increase of 38.4% over the 1990 value of 58.7 Mt.

Growth in these transport emissions is significantly higher than population growth over the same period and can be primarily attributed to increased fuel use in three sub-sectors:

- Heavy-Duty Diesel Vehicles - representing 59.0% of the total freight increase;
- Heavy-Duty Gasoline Vehicles - representing 12.0% of the total freight increase; and

- Off-Road Vehicles - representing 31.5% of the total ten-year increase.

Other modes of freight transport include Domestic Marine, and the freight portions of Domestic Air and Rail emissions. These are distinguished from their total emissions by considering data indicating their different fuel allocations to passenger versus freight lines in the case of Rail, and passenger tonne-km versus freight tonne-km, as reported by Canada's main air carriers. In comparison, LDDT's accounted for less then 1% of freight emissions in 2000.

Trucking: Heavy-duty Diesel and Gas Vehicles

Some of the growth in greenhouse gas emissions can be directly related to the growth of heavy-duty diesel and gasoline trucking primarily used for shipping freight. Difficulties arise, however, in obtaining accurate and complete data for this transport mode. Firstly, fuel consumption data, although primarily for freight, is mixed with several other uses (e.g. buses and emergency vehicles). Secondly, complete data are not available for freight shipments (often expressed in tonne-km) within the sector. Regardless, the trends in data from major for-hire truck haulers in Canada show conclusively that freight hauling by truck has increased substantially and that this activity is the primary activity attributed to Heavy-duty Gasoline and Diesel Vehicles.

The reported tonne-km of for-hire domestic and trans-border freight shipments by truck in Canada show significant growth from 1990 to 2000. Combined emissions from HDDVs and HDGVs increased steadily since 1992 in parallel with the reported domestic growth in trucking tonne-km. The rate of shipping growth has outpaced that of the emissions by almost 2:1, further reducing the industry GHG intensity by over 28.5%. Again, there is no indication of the value of those goods shipped and subsequently no trend in GHG/GDP intensity is evaluated.

Railways

Railways are heavily dependent on delivering bulk shipments of coal, potash, wheat, and lumber. As a result, fluctuating supply or demand for these products in particular affects railway freight activity and emissions. Year-to-year total activity, and therefore emissions, depend on foreign markets and Canadian crop harvests, in particular. Statistics Canada's report entitled Rail in Canada indicates 3% of the total fuel consumption was for VIA Rail, a passenger only service. As such, it was therefore assumed that freight contributed the remaining 97% of total Rail emissions.

In 2000, Rail was responsible for just below 8.0% of Canada's freight transport greenhouse gas emissions. Between 1990 and 2000, annual tonne-kilometers shipped by rail increased by 35.9% while reducing fuel consumption and producing 6.2% less GHG emissions.

Air

Transport by air moves a significant and growing percentage of freight traffic. Canadian air carriers report a 57.5% and 33.6% increase in passenger and freight related tonne-kilometres, respectively, contributing to an overall 52.5% increase in shipments while only generating an estimated 28.1% more emissions. Although air shipping of freight is the least efficient way to go with respect to GHG intensity, the trend illustrated is positive.

Also, while the passenger and freight activity levels increased over the period by varying rates, they remained in similar proportions; that is, of the total annual tonne-km reported by major Canadian air carriers since 1990, 20% is allocated to the transport of freight and 80% to that of passengers.

Marine

The emissions associated with domestic marine use of fuel in 2000 represented 6.3% of freight related greenhouse gas emissions. Since 1990, emissions have risen only 1.2% indicating low overall growth in marine shipments.

Data indicate that domestic shipping decreased 27.5% between 1990 and 2000 (measured in tonnes loaded and unloaded between Canadian ports), while international shipping increased 12.1%.

Table 3 Trends in Shipping/Freight-Related GHG Intensity

			Change Since 1990	
	1990	2000	Absolute	Relative
Rail				
GHG Emissions[1]	6.9	6.5	-0.4	-6.2%
Activity[2]	235.9	320.5	84.6	35.9%
GHG Intensity[3]	29.2	20.2	-9.1	-31.0%
Air				
GHG Emissions[1]	2.2	2.5	0.3	12.2%
Activity[2]	1.7	2.3	0.6	33.6%
GHG Intensity[3]	1274.9	1070.4	-204.5	-16.0%
Trucking				
GHG Emissions[1]	27.7	43.7	16.0	57.8%
Activity[2]	74.7	165.1	90.3	120.9%
GHG Intensity[3]	370.4	264.7	-105.8	-28.5%
Marine				
GHG Emissions[1]	5.0	5.1	0.1	1.2%
Activity[2]	53.4	38.7	-14.7	-27.5%
GHG Intensity[3]	94.6	132.0	37.4	39.6%

[1] Mt CO_2 eq
[2] Tonne Kilometre shipped (Billions)
[3] grams CO_2 eq per tonne-kilometre shipped

Glossary

Gross Vehicle Weight Rating (GVWR): The maximum allowable weight of a fully loaded vehicle, including liquids, passengers, cargo, and the tongue weight of any towed vehicle. This value is defined by the manufacturer and is based on vehicle design.

Heavy-Duty Vehicles: Any vehicle rated at more than 3900 kg GVWR or designed to carry more than 12 persons at a time. Typical icons in this category include tractor-trailers, city and highway buses and utility vehicles such as ambulances and fire trucks but also includes Light-Duty Trucks with GVWR greater than 3900 kg (such as some heavier full size pick-up trucks and work vans).

Light-Duty Trucks: This category includes pick-up trucks, mini-vans and SUVs with a GVWR of 3900 kg or less which are designated primarily for transportation of light-weight cargo or that are equipped with special features such as four-wheel drive for off-road operation. It includes both LDGT and LDDT.

Light-Duty Vehicles: This category contains what we would commonly refer to as "cars" and includes LDGV, LDDV and alternatively fuelled vehicles used primarily for passenger transport.

Tonne-Kilometre: An expression of weight (mass) multiplied by distance from origin to destination for each freight shipment. This is the standard output metric for the shipping industry.

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CANADA'S GREENHOUSE GAS INVENTORY

GHG Trends Information from Environment Canada's Greenhouse Gas Division

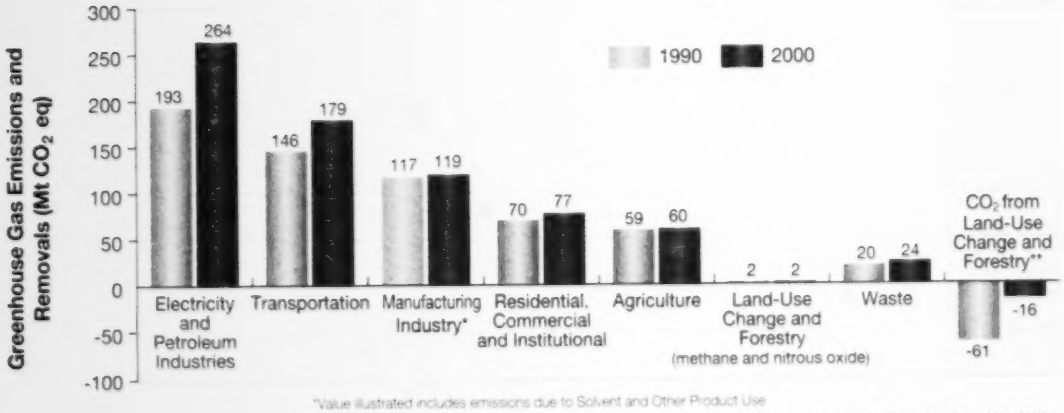
Manufacturing Industry: 1990-2000

This sector encompasses a diverse array of industries - from steel, auto, and electronic manufacturing to pharmaceutical, fertiliser, pulp and paper and food production. Emissions from the various manufacturing industries result from fossil fuel combustion, from industrial processes in which greenhouse gases (GHG) are emitted as a direct by-product of those processes, and from the fugitive release of methane during the mining of coal.

- *In 2000,* the Manufacturing Industry contributed 118 megatonnes of carbon dioxide equivalent* (Mt of CO_2 eq) emissions, representing 16% of Canada's total emissions (726 Mt). Combustion emissions accounted for 59% of the sector's emissions while industrial process emissions contributed 40%. Fugitive emissions of methane from coal mining were a minor component (about 1%) of total sector emissions. Key sub-sectors include the *Other Manufacturing* and *Industrial Chemicals Industries,* which comprised 44% (52 Mt) of the total emissions in the sector, while the *Smelting and Refining Industries* and the *Primary and Other Steel Industries* combined for a further 28% of sector emissions.
- *Between 1990 and 2000,* Manufacturing Industry's emissions increased by only 1.2% and this sector's contribution to Canada's total greenhouse gas emissions declined from 19% to 16%. Overall industrial process emissions decreased from 51 Mt to 48 Mt, a 3 Mt reduction, largely from improvements in adipic acid production in the latter part of the decade. Combustion emissions increased from 63.7 Mt to 69.4 Mt, while fugitive emissions declined by half (from 2 Mt to 1 Mt). Reductions in industrial process emissions, as well as lowered emission intensities through increased energy efficiency and fuel switching, are considered to be the main factors in the relatively stable emission levels in this sector.

*Unless otherwise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a relative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.

Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000



*Value illustrated includes emissions due to Solvent and Other Product Use

**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals

M121

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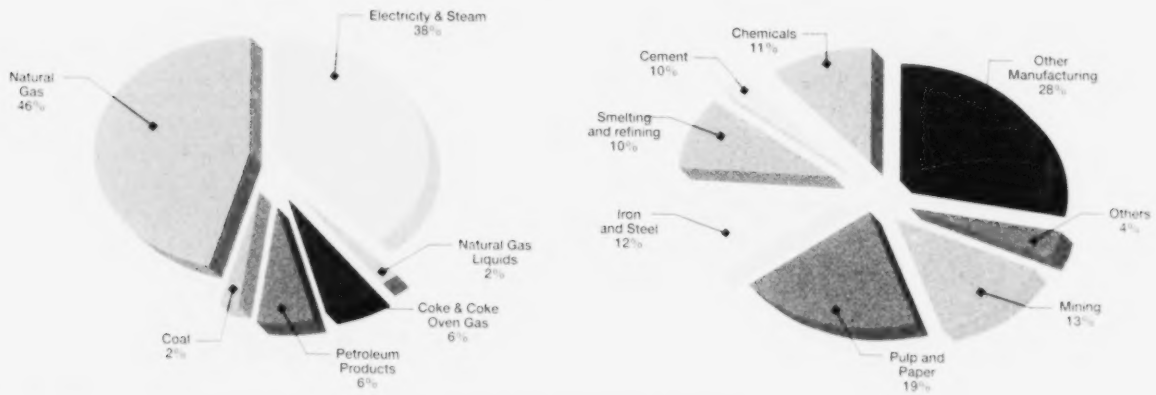
Figure 2 Manufacturing Industry's Energy Consumption, 2000

Energy Consumed: 2230 PJ



Others - includes stationary use of energy in the Forestry, Construction and Agricultural industries

Mining - includes use of natural gas by the oilsands industry

Canada's Industrial Sector

Greenhouse gas emissions in the Manufacturing Industry result from fossil fuel combustion, industrial processes, as well as fugitive releases. Combustion emissions result from the burning of fossil fuels such as natural gas, coal, and refined petroleum products (RPP) for thermal heat loads. Electricity is also a major energy source and emissions associated with the generation of electricity are discussed in more detail in the 'Electricity and Petroleum Industries: 1990-2000' fact sheet. Natural gas and electricity are the main energy sources for manufacturing industries and in 2000 contributed 46% and 38%, respectively, with respect to total demand (Figure 2).

Process emissions are due to chemical reactions and direct atmospheric releases from the use of sulphur hexafluoride and halocarbons. Fugitive emissions consist of methane releases from coal mining.

The Industry sector is comprised of eight sub-sectors:

1. *Mining*: includes all combustion and fugitive emissions of mining activity except heavy oil mining (this is included in Fact Sheet #2 - Electricity and Petroleum Industries: 1990-2000);
2. *Smelting and Refining Industries*: is comprised of process emissions from aluminium and magnesium production, as well as fuel combustion emissions;
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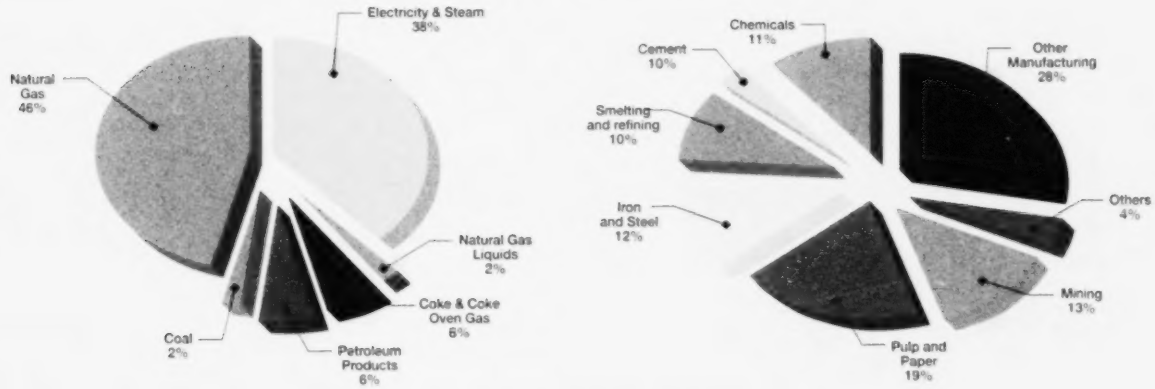

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4. *Primary and Other Steel Industries:* includes process emissions, primarily from the use of coke in reducing iron, and combustion emissions for ferrous metal industry production;
5. *Cement:* is comprised of fuel combustion emissions, as well as process emissions from the release of carbon dioxide during clinker production;
6. *Industrial Chemical Industries:* includes process emissions from the production of chemicals and combustion emissions;
7. *Other Manufacturing:* consists of combustion emissions from all other manufacturing not listed above and also consist of process emissions from the following industrial activities: the Pulp & Paper Industry, the use of halocarbons and limestone, the production of lime and lubricating oils etc.; and
8. *Other Industries:* consists of stationary fuel combustion emissions from the construction, forestry and agricultural industry.

Manufacturing Industry's Emission Trends: 1990 to 2000

In the 1990 to 2000 period, sector emissions increased by 1.2% from 117 Mt to 118 Mt. Table 1 provides the emission contributions from fuel combustion, process and fugitive sources. As is evident from the table, due to the many industries within the Manufacturing Industry sector, a variety of sub-sector trends contribute to the overall emissions.

Since 1990, process emissions decreased from 51 Mt to 48 Mt, while fuel combustion emissions increased from 63.7 Mt to 69.4 Mt. The addition of emission mitigation technology in adipic acid production has reduced process emissions within the Industrial Chemical Industries by about 10 Mt.

The only fugitive emissions are from coal mining, which are a minor contributor to sector totals. Due to mine closures, fugitive emissions from coal mines between 1990 and 2000 decreased from 2 Mt to 1 Mt.

Sector trends in greenhouse gas emissions result from changes in:

- Production output within the industry (product demands);
- Fuel Switching (switching to less greenhouse gas intensive fuels); and
- Production processes and process efficiency (installation of emission abatement technologies or using fuel more efficiently);

Overall, the sector has seen a slight increase of 1.2% in emissions relative to a 50% increase in gross production output and a 36% increase in Gross Domestic Product (GDP). (CIEEDAC, 2002) Process emission reductions and lowering of emission intensities through fuel switching to less GHG intensive fuels and energy efficiency measures have contributed to the relatively stable emission levels of the sector. The precise contributions to changing emissions of fuel switching and efficiency factors are difficult to identify because of the complex and multilayered use of energy in the Manufacturing Industry sector. Fuel use trends, however, indicate increasing use of less GHG intensive fuels by the Pulp & Paper Industry and Primary and other Steel Industry.

Sub-Sector Emission Trends

Greenhouse gas emission trends within the Manufacturing Industry are influenced by changes within key sub-sector industries. Figure 3 provides the 1990 to 2000 trends for eight sub-sectors. Only the Industrial Chemical Industries category exhibited a significant decline in overall emissions, but there are no large sub-sector increases.

While large absolute emission changes are not immediately evident, there have been changes within specific industry categories. These emission trends are discussed below on a sub-sector and industry category basis. To link emission trends to industry performance, production trends have been tracked based on physical output. When production data are not available, GDP output data are used, although this is a less certain means of tracking performance*.

** Industrial GDP output can be misleading as a trend indicator because of fluctuations in industry sub-sector commodity prices not accounted for by the consumer price index adjustments.*

Table 1 Manufacturing Industry's Emission Trends by Combustion, Process and Fugitive Sources, 1990 to 2000, Mt CO_2 eq

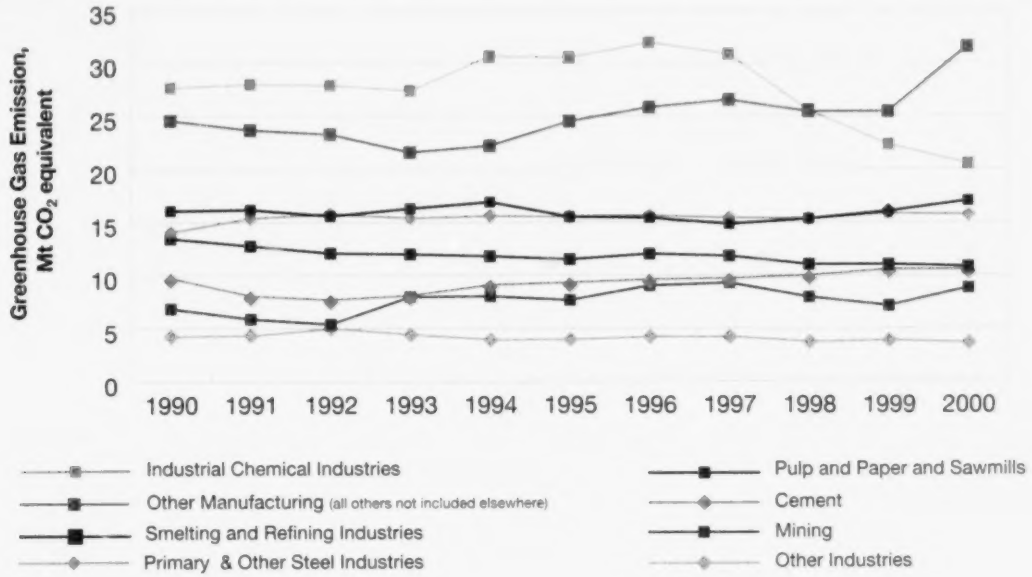
Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
MANUFACTURING INDUSTRIES	**117**	**114**	**113**	**113**	**118**	**118**	**123**	**122**	**114**	**112**	**118**
Fuel Combustion	**63.7**	**60.3**	**60.1**	**59.7**	**62.4**	**62.8**	**66.1**	**66.4**	**62.7**	**62.7**	**69.4**
Mining[1]	5.0	3.8	3.6	6.1	6.3	5.9	7.2	7.6	6.5	6.0	7.9
Smelting and Refining Industries	3.2	2.6	2.8	2.7	3.3	3.1	3.5	3.2	3.4	3.3	2.8
Pulp and Paper and Sawmills	13.5	12.8	12.1	12.0	11.8	11.5	12.0	11.8	11.0	11.0	10.8
Primary & Other Steel Industries	6.5	6.5	6.7	6.7	7.5	7.0	7.3	7.3	7.0	7.3	7.2
Cement	3.7	3.2	3.2	3.2	3.6	3.7	3.6	3.6	3.7	4.0	4.0
Industrial Chemical Industries	7.1	7.5	7.5	7.3	8.5	8.5	8.8	8.9	8.6	8.5	8.4
Other Manufacturing all others not included elsewhere	20.5	19.5	19.2	17.2	17.5	19.1	19.4	19.8	18.8	18.8	24.8
Other Industries	4.3	4.4	5.0	4.4	4.0	4.0	4.2	4.2	3.7	3.9	3.6
Industrial Process	**51**	**52**	**51**	**52**	**54**	**54**	**55**	**54**	**50**	**48**	**48**
Smelting and Refining Industries	13	14	13	14	14	12	12	12	12	13	14
Primary & Other Steel Industries	7.6	8.9	9.1	8.8	8.1	8.4	8.3	8.1	8.3	8.5	8.5
Cement	5.9	4.7	4.3	4.7	5.3	5.4	5.8	5.9	6.1	6.3	6.3
Industrial Chemical Industries	21	21	20	20	22	22	23	22	17	14	12
Other Manufacturing all others not included elsewhere	4.1	4.2	4.1	4.4	4.7	5.4	6.3	6.8	6.6	6.6	6.7
Fugitive (Mining[1])	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**

Notes: Due to rounding, individual values may not add up to totals.
[1] A small proportion of emissions from the Upstream Petroleum Industry is accounted for in the Mining sector due to data limitations.

Mining

Overall, the mining industry emitted 7.4% more greenhouse gas emissions in 2000 than in 1990, of which 89% of emissions were due to the combustion of fossil fuels. Combustion emissions increased 58% and total energy use rose 28% over the period (Table 1); however, no dramatic trends in fuel switching have been observed. In addition, fugitive emissions of methane from underground coal mines dropped by over 50% due to mine closures.

Figure 3 Manufacturing Industry's Greenhouse Gas Emission Trends, 1990 to 2000



Smelting and Refining Industries

Emissions from the Smelting and Refining Industries sub-sector increased by about 5% over the 1990 to 2000 period. During this period, combustion emission decreased by 13%, while process emission increased by 10% (Table 1). Within the sub-sector, process emissions from magnesium smelting decreased more substantially. Magnesium producers have improved process controls which has resulted in a 20% reduction in SF_6 emissions since 1990, despite a 300% increase in production (NRCan, 2002). From 1990 to 2000, aluminium production increased 52% while process emissions increased by only 17% (NRCan, 2002). Process emissions for aluminium production are due to anode events during the reduction of alumina to aluminium creating high global warming potential greenhouse gases called perfluorocarbons (PFCs) (which includes carbon tetrafluoride (CF_4) and hexafluoroethane (C_2F_6)). Reduced emissions can be attributed to better control of smelting through electronic monitoring (Figure 4).

Pulp and Paper and Sawmills

Greenhouse gas emissions from the pulp and paper industry decreased 20% from 1990 to 2000, while product output increased 12% (CIEEDAC, 2002). (Figure 5) These diverging trends result from a 41% reduction in coal and fuel oil use and increased use of natural gas and electricity by 10% and 26%, respectively. (Statistics Canada, 2001) For example, natural gas provides more than twice the energy supplied by coal and refined petroleum products to the sub-sector. While natural gas demand has increased by 10%, the use of the more GHG intensive fuels has decreased by 40% since 1990.

Primary and Other Steel Industries

While primary steel industry production grew 35% from 1990 to 2000 (CIEEDAC, 2002) greenhouse gas emissions increased by only 12%. Both process and combustion-related emissions have increased by 11% and 12%, respectively. Process emissions are primarily from the use of coke in reducing iron while combustion emissions are for all ferrous metal industry production.

Figure 4 Smelting and Refining Industries – Indexed Emission Trends, 1990 - 2000

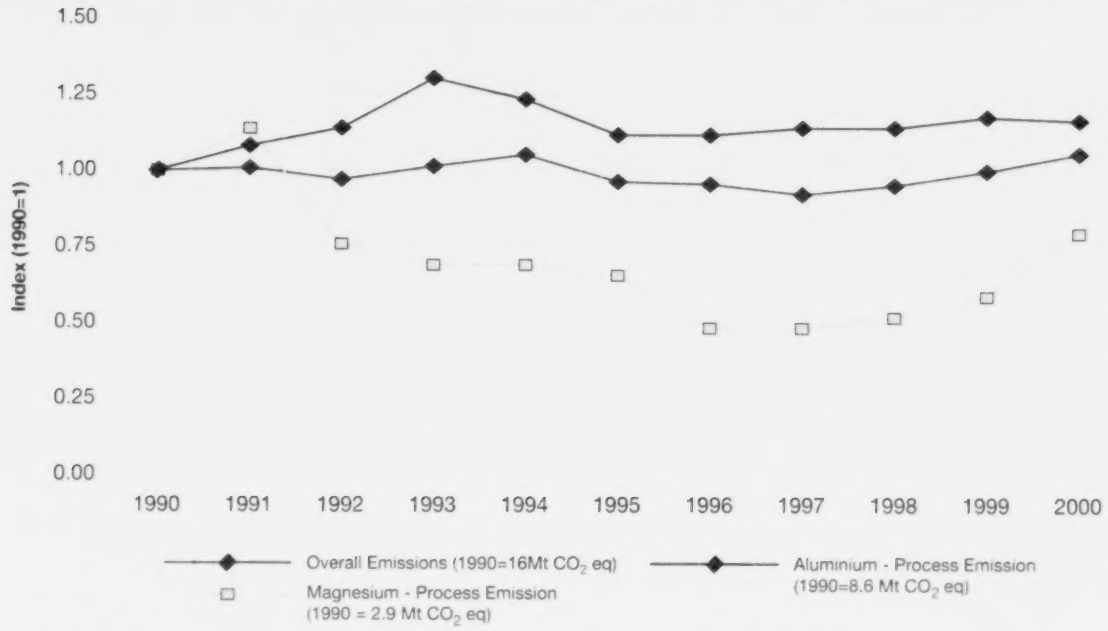


Figure 5 Cement, Primary & Other Steel and Pulp & Paper Industries' Emission Intensities, 1990-2000

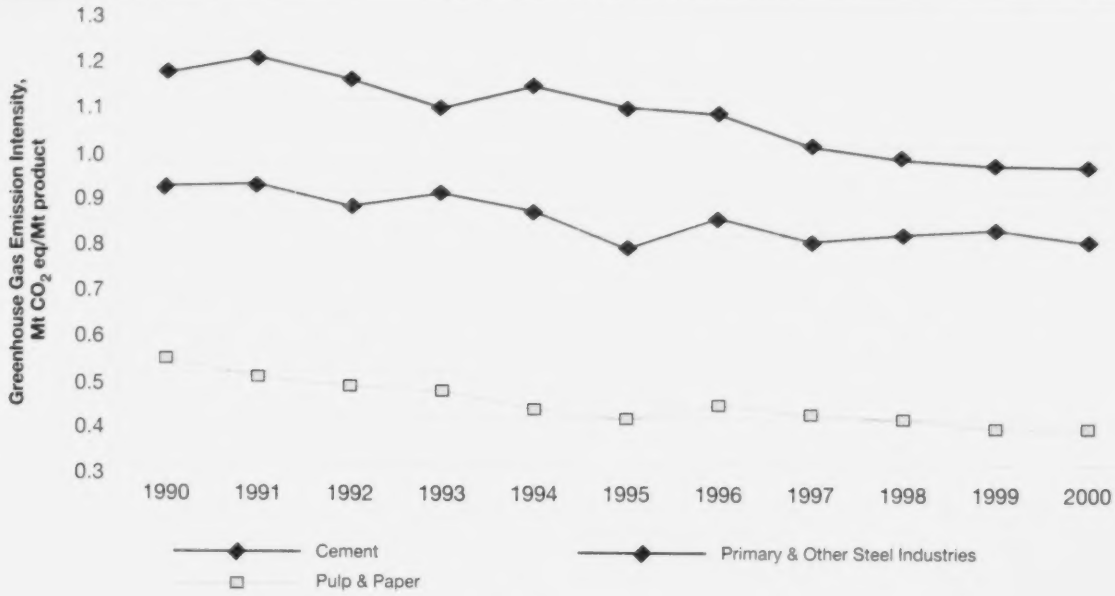
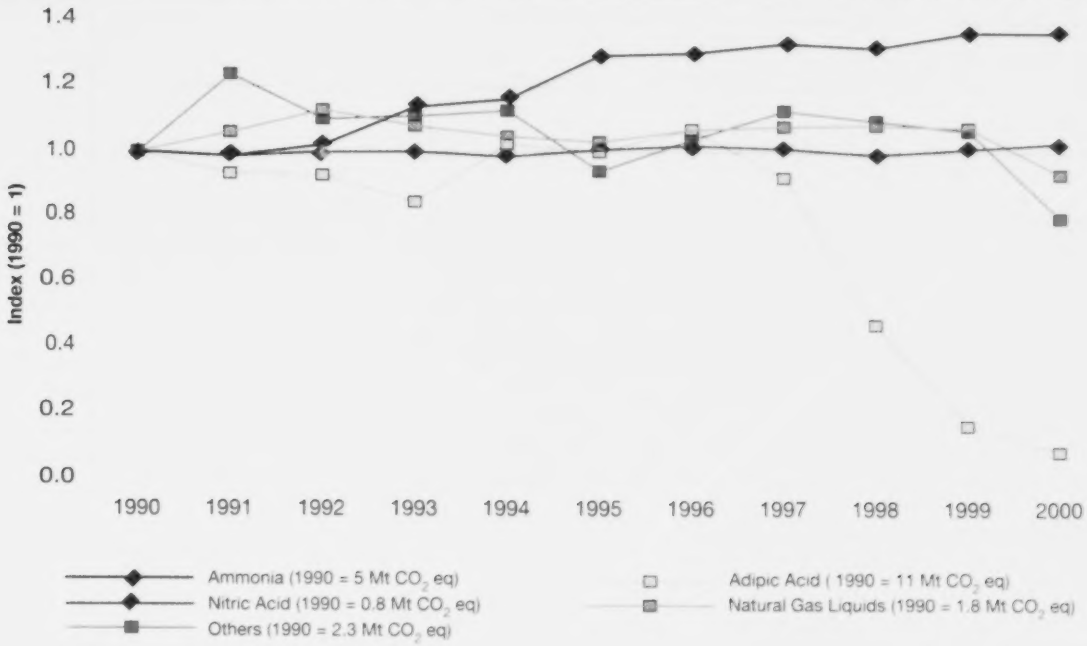


Figure 6 Industrial Chemicals – Process Emission Indexed Trends, 1990-2000



Data indicate that decreasing combustion emission intensities are due to increased efficiencies in energy use, as well a 52% increased use of natural gas, with an accompanying 33% decline in the use of refined petroleum products. (Figure 5)

Cement

Emissions from cement production were 10 Mt in 2000, an increase of 0.7 Mt from the 1990 level. The trends in emissions closely follow cement production levels. Process emissions constitute 62% of total emissions in this category and result from the release of carbon dioxide during clinker production. While overall emission intensity decreased by 13%, combustion emissions have increased due to fuel switching toward more GHG intensive fuels. The use of natural gas has decreased by 24% since 1990, while there was a 23% rise in coal and 60% rise in coke use (Statistics Canada, #57-003). Total emissions track production closely, with little change in GHG intensity over the period (Figure 5).

Industrial Chemical Industries

Emissions from the Industrial Chemical Industries sub-sector decreased from nearly 28 Mt to 20 Mt over the 1990 to 2000 period. Approximately three-quarters of the sub-sector's total greenhouse gas emissions are process emissions, which decreased 41% since 1990.

The installation of emission abatement technology at the sole adipic acid production plant in Canada, has resulted in a 10 Mt reduction of process related nitrous oxide emissions (Figure 6). On the other hand, ammonia production process emissions increased 37% over the period, while process emissions associated with nitric acid production increased slightly by 3%. The sub-sector has seen a 22% increase in GDP since 1990 (CIEEDAC, 2002). The resulting 39% decline in GHG intensity is due in large part to reductions in adipic acid process emissions.

Industrial Chemical Industries' combustion emission grew by 18%, from 7.1 Mt to 8.4 Mt since 1990. In terms of energy sources, natural gas is the primary fuel for combustion purposes in this sub-sector; its use grew by over 18% while the minor usage of refined petroleum increased 22%.

Other Manufacturing

Overall emissions in the Other Manufacturing sub-sector increased 28% from 25 Mt in 1990 to 32 Mt in 2000. Fuel combustion produced nearly 80% of emissions in this sub-sector; these emissions increased by 21% since 1990.

The increase in emissions may be due to increased activity and therefore increased fuel use. For instance, this sub-sector, which is heavily dependent on natural gas, has increased its use by 26% since 1990. Coal and coke use has respectively risen by 32% and 8%. Refined petroleum products use grew by 6% and natural gas liquid use has declined by about 41%, while electricity consumption has increased by 25% (Statistics Canada, #57-003).

In 2000, 0.9 Mt (3%) of overall greenhouse gas emissions from Other Manufacturing industries resulted from the use of halocarbons (HFCs/PFCs). Halocarbon emissions have increased by 0.4 Mt from 1995 levels. Halocarbons are used as ozone depleting substance replacements, such as CFCs and are primarily used as coolants in refrigeration and in both stationary and mobile air conditioning units. Other industrial uses of HFCs/PFCs consist of the electronics industry, the semiconductor industry, and by aerosol and fire extinguisher producers.

Other Industries

In 2000, the stationary fuel combustion contribution of greenhouse gas emissions by the Other Industries sub-sector (which includes the categories of construction, agriculture and forestry) was 3.6 Mt, a decline of about 0.7 Mt from 1990.

Solvents and Other Product Use Sector

This sector accounted for less than 0.1% (0.5 Mt) of Canada's total greenhouse gas emissions in 2000. Emissions in this sector are from the use of nitrous oxide as anaesthetic and propellant; and have increased by 11% since 1990.

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CANADA'S GREENHOUSE GAS INVENTORY

GHG Trends Information from Environment Canada's Greenhouse Gas Division

Residential, Commercial & Institutional Sectors: 1990 - 2000

The Residential, Commercial & Institutional (RCI) sector of the Canadian Greenhouse Gas Inventory includes emissions from fuel combustion in buildings for space heating and cooling* (excluding electricity use) and water heating.

- *In 2000*, this sector contributed about 11% of Canada's 726 megatonnes of carbon dioxide equivalent** (Mt CO_2 eq) greenhouse gas emissions. Total emissions in 2000 from this sector were 76.9 Mt - 45 Mt from the Residential sub-sector and 31.9 Mt from the Commercial & Institutional sub-sector.

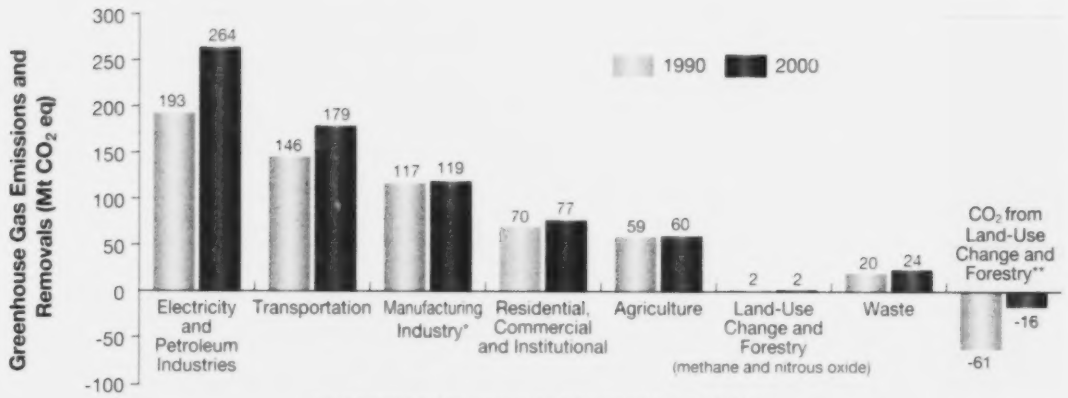
Between 1990 and 2000, overall greenhouse gas emissions grew 10% from a base of 69.8 Mt. Residential sub-sector emissions increased 2.3% while Commercial & Institutional sub-sector emissions grew 23%. Greenhouse gas emission and fuel consumption associated with space conditioning within the RCI sector is greatly influenced by year to year temperature fluctuations. Overall changes in emissions can be attributed to:

- *use of energy*. There has been an increase in energy use because of growth in both sub-sectors. Increased energy use, however, has been offset by mitigating factors that include energy efficiency improvements in building stock and warmer weather; and
- *substitution of fuel oil by natural gas*, a less carbon intensive fuel.

*Gas fired space cooling is a potential small source of greenhouse gas emissions.

**Unless otherwise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this have been shortened to Mt. This concept provides a relative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.

Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000



*Value illustrated includes emissions due to Solvent and Other Product Use

**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals

Canada's RCI Sector

The RCI sector accounts for greenhouse gas emissions from all fossil fuel combustion in buildings. Overall the RCI sector is not a major contributor to national emissions: in 2000 its contribution was about 11% of the national total. The Residential sector contributed 6.2% , while the Commercial & Institutional sector contributed 4.4%.

Buildings in this sector encompass a range of uses - from detached single family dwellings and apartment buildings, to retail, office and institutional buildings serving business, industry, government, finance, education, health, warehouse, recreation and social service purposes. Omitted from this sector are buildings used in manufacturing, mining and construction (these are included in Fact Sheet #4 - Manufacturing Industry: 1990-2000).

The heating or cooling of building interiors, known as space conditioning, and water heating are the sources of this sector's emissions. In addition, they are important energy consuming activities in the operation of buildings. In 2000, about 82% and 66% of total energy demand in the residential and commercial sub-sectors, respectively, was for space conditioning and water heating (Natural Resources Canada, 2002).

The Canadian Greenhouse Gas Inventory (CGHGI)

The Canadian Greenhouse Gas Inventory is developed, compiled, and reported annually by the Greenhouse Gas Division of Environment Canada, and utilizes methods and models developed in-house by engineering and scientific staff, as well as published data, data developed by industry, or methods developed by the Intergovernmental Panel on Climate Change (IPCC, 1997).

The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).

The inventory uses an internationally agreed to reporting format that groups emissions and removals into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry, and Waste. The 2000 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, uses a modified sector approach to facilitate the use of information by the public.

RCI Emission Trends

Over the 1990 to 2000 period, overall greenhouse gas emission growth in this sector was relatively flat. Emissions from the Residential sub-sector grew by 2.5% while Commercial & Institutional emissions increased by 23%. Figure 2 illustrates the trend in emissions for both the Residential and Commercial & Institutional sub-sectors for the period 1980 to 2000.

In order to understand RCI trends, it is important to examine influencing factors, and hence, emissions. Trends in emissions can be influenced by four important factors:

1. real estate activity within the sector (the growth or decline of heated/cooled building space);
2. changes in efficiency of energy use;
3. changes in weather (which would require more or less fuel for heating or cooling); and
4. substitution of fuels with differing carbon intensities.

Growth in Residential and Commercial Activity

The Residential, Commercial and Institutional sub-sectors all experienced significant growth in activity between 1990 and 2000. An 18 % growth in residential floor space and a 24% growth in commercial floor space were estimated for 2000 (Natural Resources Canada, 2002). Without other influences, growth in sector activity may have had the greatest impact on energy use, giving rise to a potential increased energy demand of 500 PJ, or 23% over 1990. The impact on greenhouse gas emissions by this potential increase in energy use, however, was ameliorated by other factors described below.

Electricity Emissions

For accounting purposes, Canada's Greenhouse Gas Inventory attributes emissions from electricity only to production at the generation source. Demand for electricity in the RCI sector, whether for space heating, cooling, or other purposes, is included in Fact Sheet #2 - Electricity and Petroleum Industries: 1990-2000.

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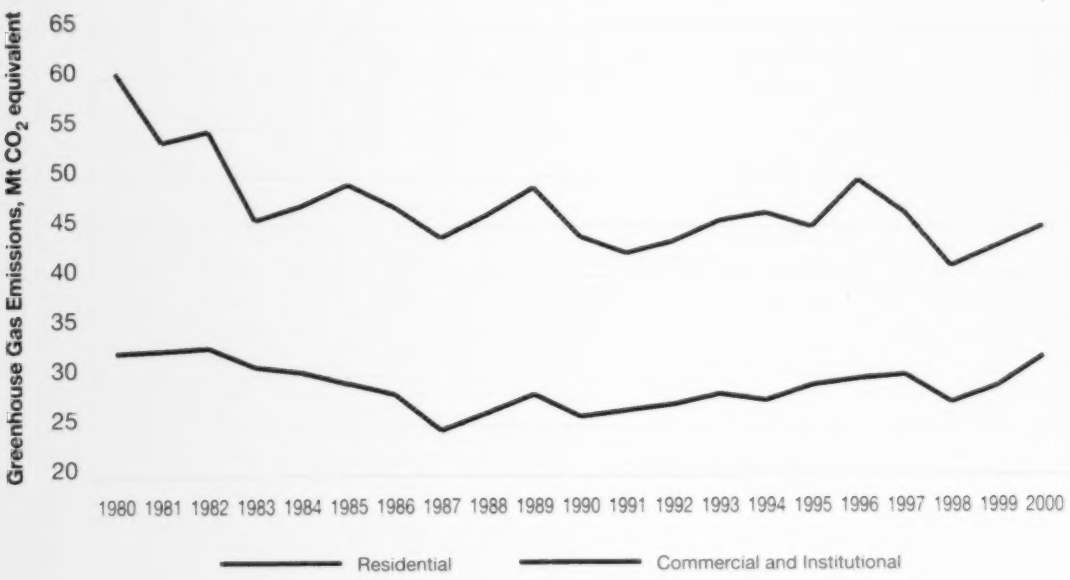
Figure 2 RCI Sector's Greenhouse Gas Emission Trends, 1980 to 2000



Increases in Energy Efficiency

Energy efficiency increases within buildings (for example, increased insulation and high efficiency furnaces) was the major contributor to dampening overall energy demand over the period. In the Residential sub-sector, increases in efficiency decreased potential growth in space heating energy use by 196.6 PJ (Natural Resources Canada, 2002). In the Commercial & Institutional sub-sector, potential growth in all energy use decreased by 23.2 PJ. Energy efficiency improvements, therefore, are significant contributors to reducing the growth of greenhouse gas emissions.

Changes in Weather

The other factor influencing energy use, and hence emission trends, is weather. Figure 3 tracks greenhouse gas emission trends in the RCI sector against heating degree days (HDD). From the figure, it is evident that there is a general coincidence in the trends. The Commercial & Institutional sub-sector is less likely to show the influence of heating degree days because of its widespread use of gas-fired absorption air conditioning.

In 2000, heating degree days were 1.6% lower than in 1990 (Statistics Canada, #57-003). In warmer years with lower heating degree days, decreased energy use for heating is offset because the requirement for air conditioning likely increases with more cooling degree days (CDD).

Fuel Substitution

Fuel substitution away from carbon intensive fuels can ameliorate greenhouse gas emissions. This has been the trend in the RCI sector. Table 1 compares the trends in all fuel use for the RCI sector for the years 1990 to 2000.

There has been a clear trend over the last 11 years for the substitution of fuel oil by natural gas in the RCI sector. While electricity, coal and propane have maintained their contributions to energy used, the natural gas contribution has increased 3% and fuel oil has decreased by the same proportion. The carbon intensity of natural gas is 25% less than that of fuel oil, leading to emission reduction trends.

By examining climatic and population influences, as illustrated in Figure 4, the decline in RCI emission intensity demonstrates the effect of fuel switching and energy efficiency improvement.

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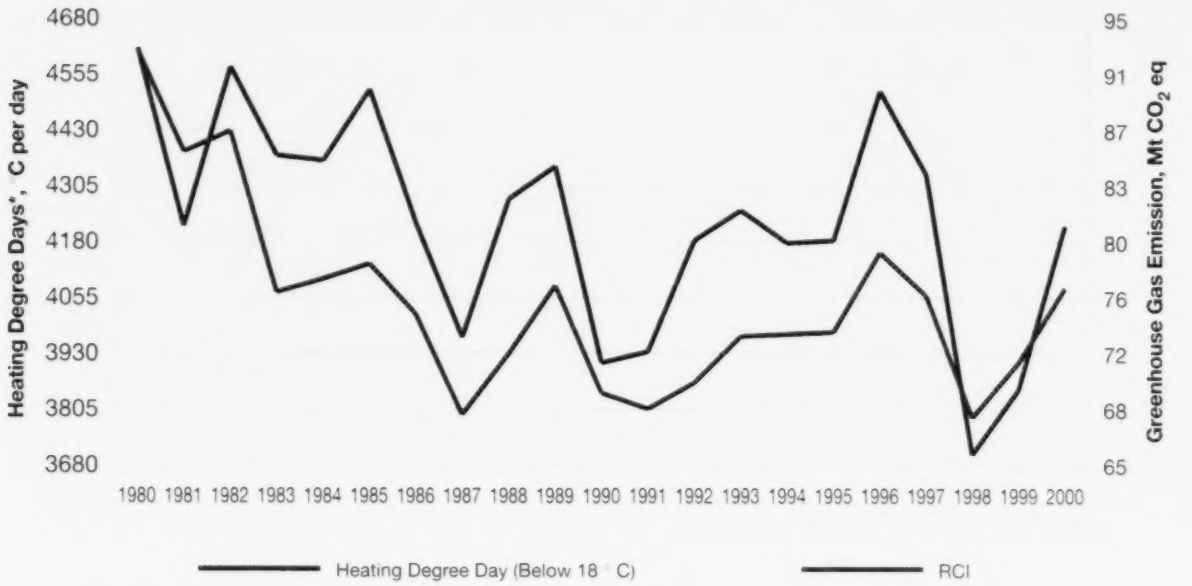
Figure 3 RCI sector Trends Related to Heating Degree Days (HDD), 1980 to 2000



* Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

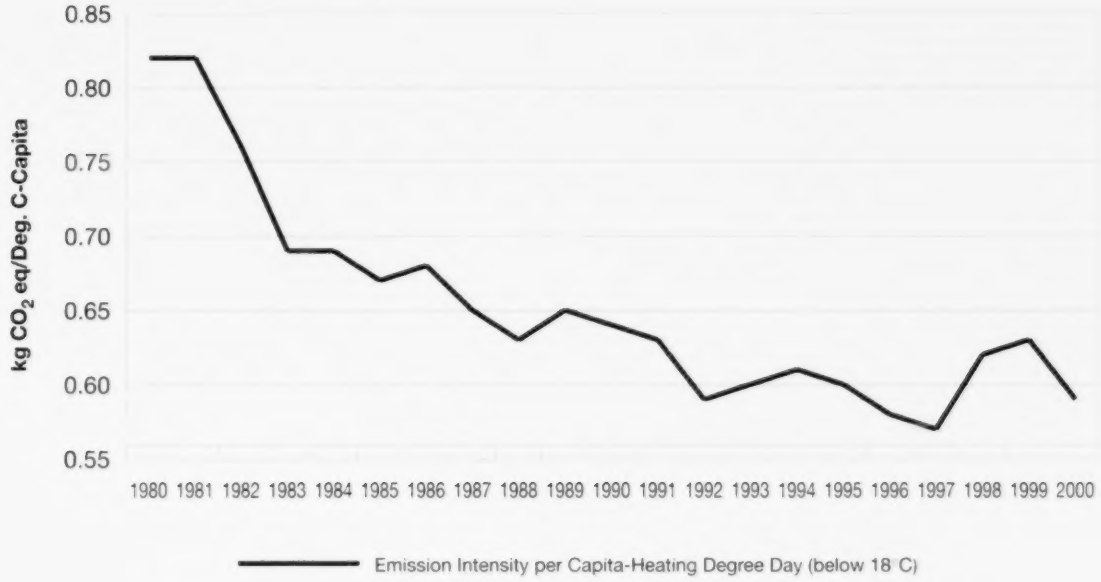
Table 1 RCI Greenhouse Gas Emissions and Energy Consumption: 1990 to 2000

	Greenhouse Gas Emissions	Energy Consumption[1]					
		Energy Total	Primary Electricity*	Coal	Natural Gas	Natural Gas Liquids	Fuel Oil
	Mt CO_2 equivalent	PJ	Percent Contribution (%)				
1990	69.8	2258	38	0.1	41	1.6	20
1991	68.8	2241	39	0.1	42	1.8	18
1992	70.5	2283	38	0.1	42	1.6	18
1993	73.6	2357	38	0.1	44	1.5	17
1994	73.8	2384	37	0.1	44	1.9	17
1995	73.9	2405	37	0.1	44	2.3	16
1996	79.3	2512	36	0.1	46	1.9	16
1997	76.4	2485	37	0.1	44	2.1	16
1998	68.2	2326	39	0.1	43	1.8	17
1999	71.9	2418	38	0.1	44	1.9	17
2000	76.9	2565	37	0.1	44	1.8	17

*For accounting purposes, GHG emissions attributed to RCI electricity consumption are included in Fact Sheet #2, Electricity and Petroleum Industries.

[1]Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

Figure 4 RCI Emission Intensities, 1980 to 2000



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Glossary

Heating Degree Day (HDD): An indicator of winter heating loads. The annual sum of the degrees of average daily temperatures for all days below 18°C.

Cooling Degree Day (CDD): An indicator of summer cooling loads. The annual sum of the degrees of average daily temperatures for all days above 18°C.

Carbon intensity: The proportion of molecular carbon to the energy content of a fuel. Since nearly all carbon is released as a gas on combustion of fuels, high carbon intensity fuels produce more CO_2 per unit of heating than low intensity fuels.

CANADA'S GREENHOUSE GAS INVENTORY
GHG Trends Information from Environment Canada's Greenhouse Gas Division

Land-Use Change and Forestry: 1990-2000

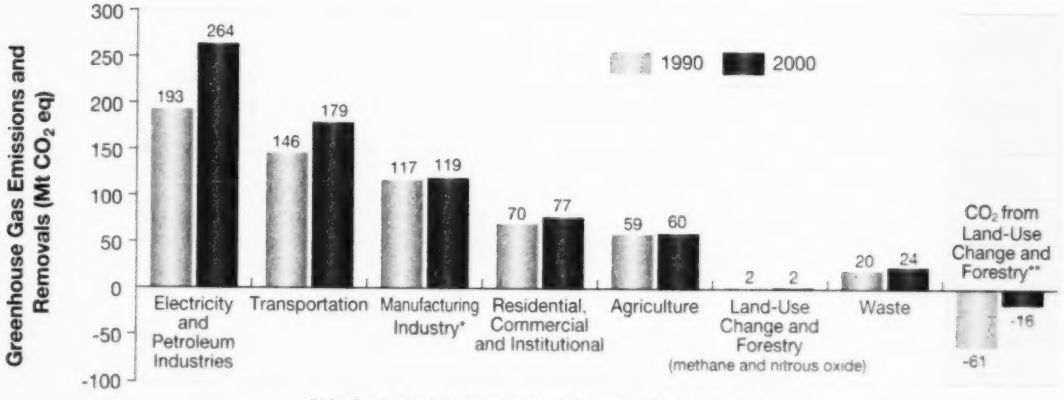
The Land-use Change and Forestry (LUCF) sector of the Canadian Greenhouse Gas Inventory (CGHGI) includes the contribution to greenhouse gas emissions and removals of forest management, human-induced fires, and changes in the way land is used.

In view of Canada's 200 million hectares of managed lands, clearly land-use and land-use practices embody a significant component of the Canadian way of life.

- *In 2000*, Canada's LUCF sector removed from the atmosphere an estimated 14 megatonnes of carbon dioxide equivalent* (Mt CO_2 eq). The dominant greenhouse gas is carbon dioxide (CO_2), with small contributions of methane (CH_4) and nitrous oxide (N_2O). As per current IPCC Guidelines (IPCC, 1997), carbon dioxide fluxes in the LUCF sector are excluded from national inventory totals. Methane and nitrous oxide emissions from the LUCF sector are included in the Canadian totals and represent about 0.3% (2 Mt) of national total emissions (726 Mt) in 2000.
- *Between 1990 and 2000*, the LUCF sector, calculated as the sum of the net carbon dioxide flux and non-carbon dioxide emissions, remained a net sink. The general trend indicates a decline in the net removal, from 59 Mt in 1990 to 14 Mt in 2000. This trend results from an 18% increase in harvest emissions during the period, and reflects the high variability in emissions from forest fires. If the LUCF net carbon dioxide removals were included in the national totals, it would result in a reduction of total Canadian emissions of 10% in 1990, and 2% in 2000. If carbon storage in harvested wood products was accounted for, the decline in the net carbon dioxide removal would be much smaller over the period, by up to 60%, depending on the selected accounting approach.

*Unless otherwise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a measure of the impacts of different gases on global warming, with the effect of carbon dioxide being equal to one.

Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000



*Value illustrated includes emissions due to Solvent and Other Product Use
**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals

Table 1 2000 Greenhouse Gas Emissions and Removals Summary for the LUCF Sector

LUCF Category	Carbon Dioxide Mt	Methane and Nitrous Oxide Mt CO_2 eq	LUCF Category Total Mt CO_2 eq
Forest Management	-28	not estimated	-28
Land-Use Changes	5	not estimated	5
Anthropogenic Forest Fires			
inside Wood Production Forest	included in Forest Management	2	2
outside Wood Production Forest	6	0.5	6.5
Total	**-16**	**2.5**	**-14**

Notes: Shaded areas indicate values that are not included in the national inventory totals.
Due to rounding, individual values may not add up to the sector total.
Removals are shown as negative values.

Canada's LUCF Sector

The LUCF sector shares, with agricultural soils, two distinctive characteristics: they include both emissions and removals of greenhouse gases to and from the atmosphere, and they involve close interactions of human activities and natural processes.

Greenhouse gases are emitted to the atmosphere through the decomposition or burning of living and dead organic matter. They are absorbed by vegetation through photosynthesis and stored in biomass and in soils. Both emissions and removals of greenhouse gases are large fluxes resulting from minute processes dispersed over a vast land area. Changes in land-use practices directly alter the size and rate of these natural exchanges of greenhouse gases between the terrestrial landscape and the atmosphere, both in the present and over long periods of time. Understanding and measuring the components of these natural fluxes that are due to human intervention represent unique scientific and accounting challenges.

For the purpose of describing the trends in LUCF emissions and removals in Canada, the LUCF sector is divided into the following three categories: Forest Management; Land-use Changes; and Anthropogenic Forest Fires (Table 1).

In 2000, the LUCF sector accounted for a net removal of 14 Mt CO_2 eq. The largest and most influential category on total greenhouse gas emissions and removals is Forest Management, with a net removal of nearly 30 Mt CO_2 (Table 1). However, carbon dioxide from the LUCF sector is not included in the national inventory totals; hence, the only contribution by the LUCF sector to these totals are emissions of approximately 2 Mt CO_2 eq arising from anthropogenic forest fires.

The Canadian Greenhouse Gas Inventory (CGHGI)

The Canadian Greenhouse Gas Inventory is developed, compiled, and reported annually by the Greenhouse Gas Division of Environment Canada, and utilizes methods and models developed in-house by engineering and scientific staff, as well as published data, data developed by industry, or methods developed by the Intergovernmental Panel on Climate Change (IPCC, 1997).

The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).

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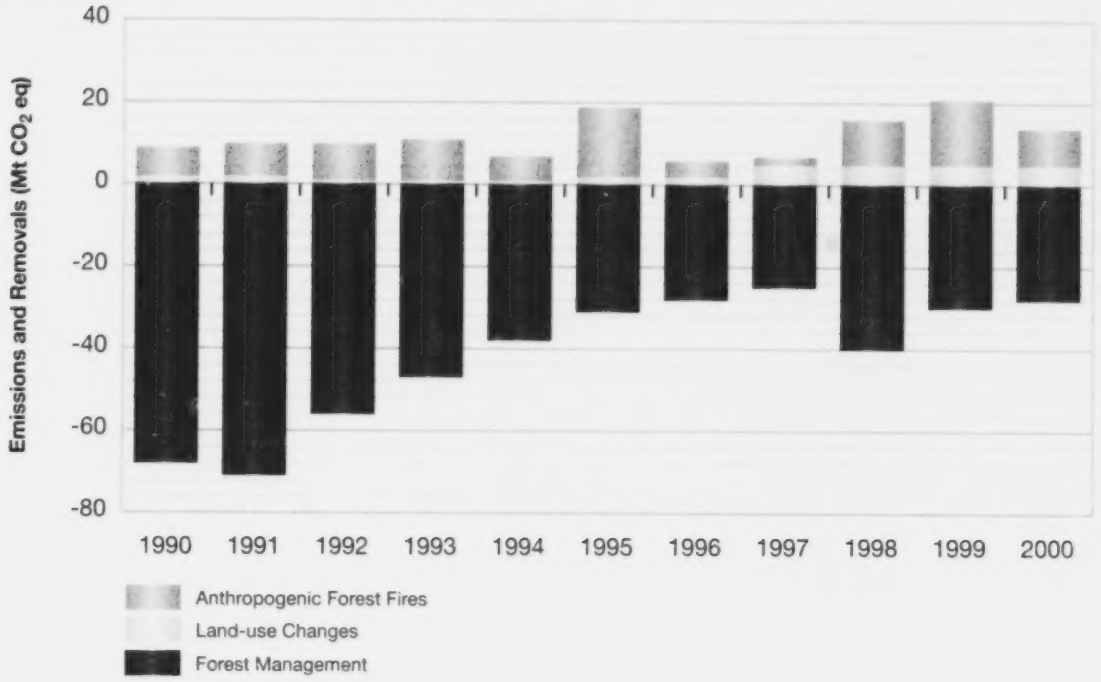
Figure 2 LUCF Sector Emissions and Removals by Category, 1990 to 2000



LUCF Sector Emissions and Removals Trends: 1990 to 2000

Over the decade, Forest Management has remained the dominant LUCF category. It generally represents at least 87% of all carbon dioxide removals in the LUCF sector and displays a trend similar to the overall sector trend, with sinks declining by 59% between 1990 and 2000.

Forest Management

Which forest?

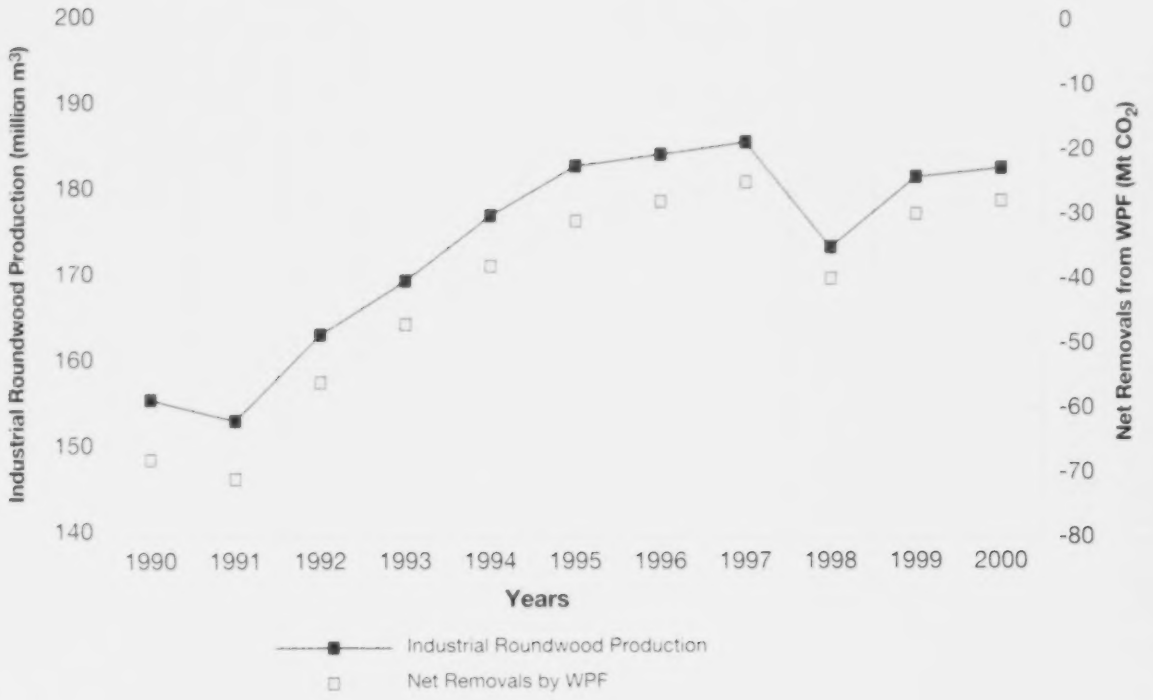
The LUCF inventory estimates carbon dioxide emissions and removals in the "managed" part of the forests, thus excluding forests not managed for wood production. In the CGHGI, this forest is identified as the "*Wood Production Forest*", and is defined as the non-reserved, stocked, timber-productive forests with access (Canadian Forest Inventory Publications). The Wood Production Forest extends over 133 million hectares (133 Mha), distributed unevenly throughout Canada.

Carbon fluxes in and out of the forest

The LUCF inventory estimates net carbon dioxide fluxes in and out of the Wood Production Forest by subtracting the carbon removed in the harvested wood from the net carbon taken up by trees in the "*growing area*" of the Wood Production Forest. This "growing area" (123 Mha) consists of the area over which trees are actively sequestering carbon through photosynthesis, and excludes overmature forests. Fluxes of carbon to and from forest soils are also excluded due to a lack of data. It is assumed that carbon dioxide emissions from fires in the Wood Production Forest are implicitly incorporated in the average growth rates. This assumption is reconsidered below, under the heading "*Uncertainty*".

Since it is assumed that the areal extent of the 'growing' forests and their average growth rates are stable over the 1990 to 2000 period, trends in carbon emissions and removals largely result

Figure 3 Trends in Industrial Roundwood Production and Carbon Dioxide Removals by the Wood Production Forest, 1990 to 2000



Carbon Accounting of Harvested Wood Products

The preparation of the Canadian Greenhouse Gas Inventory for the LUCF sector closely follows the Guidelines published by the Intergovernmental Panel on Climate Change (IPCC, 1997). The IPCC default approach currently requires that all the carbon in the wood harvested from forests is considered to be emitted to the atmosphere in the year of harvest; hence, it does not account for long-term carbon storage in harvested wood products and landfills. Where these pools do in fact increase, the default method overestimates carbon dioxide emissions from forest management. The IPCC has not yet recommended an alternative approach for the accounting of carbon storage in wood products.

While awaiting further guidance from the IPCC, Canada has produced estimates of the contribution of the wood product sector to net carbon emissions and removals from its managed forest, using two alternative approaches. Both alternative approaches markedly reduce the apparent impact of industrial forestry activity on the carbon balance of the Wood Production Forest. In 2000, depending on the approach selected, harvest emissions vary from 261 Mt CO_2 (current default method) to as low as 169 Mt CO_2. Different accounting for carbon in exported wood products explains a large part of the variability in harvest emissions.

Very little information is available on the wood waste stream in Canada, specifically on the composition and fate of wood-based material landfilled annually. Landfills are a poorly known, yet potentially vast carbon depository.

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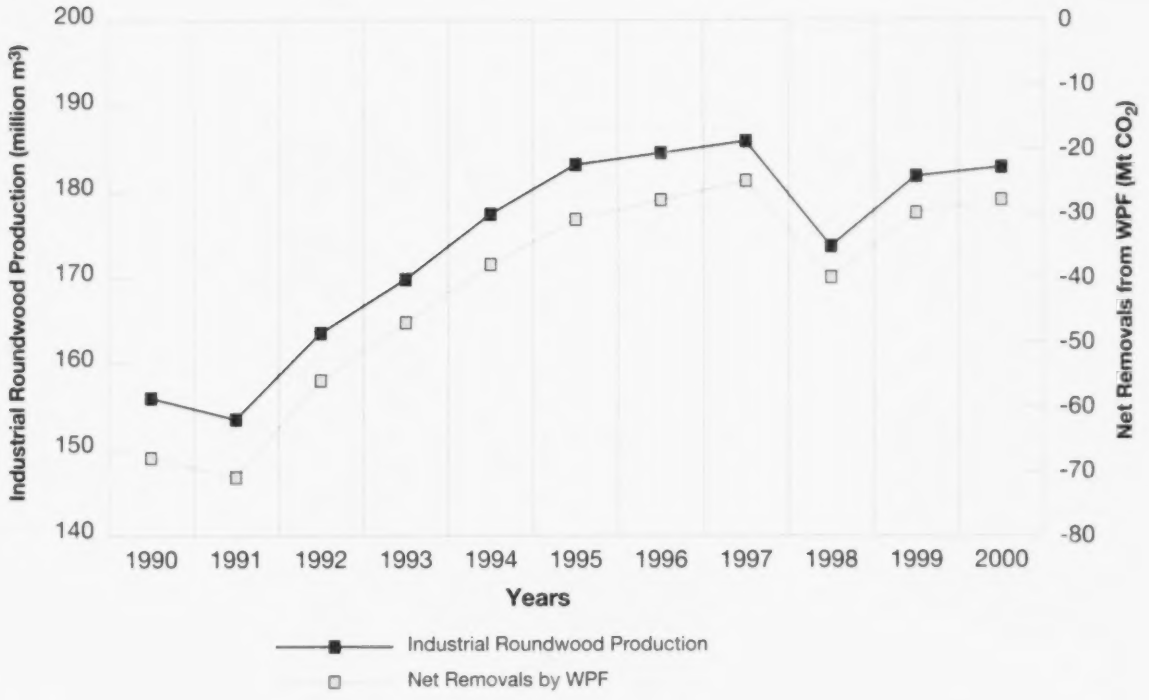

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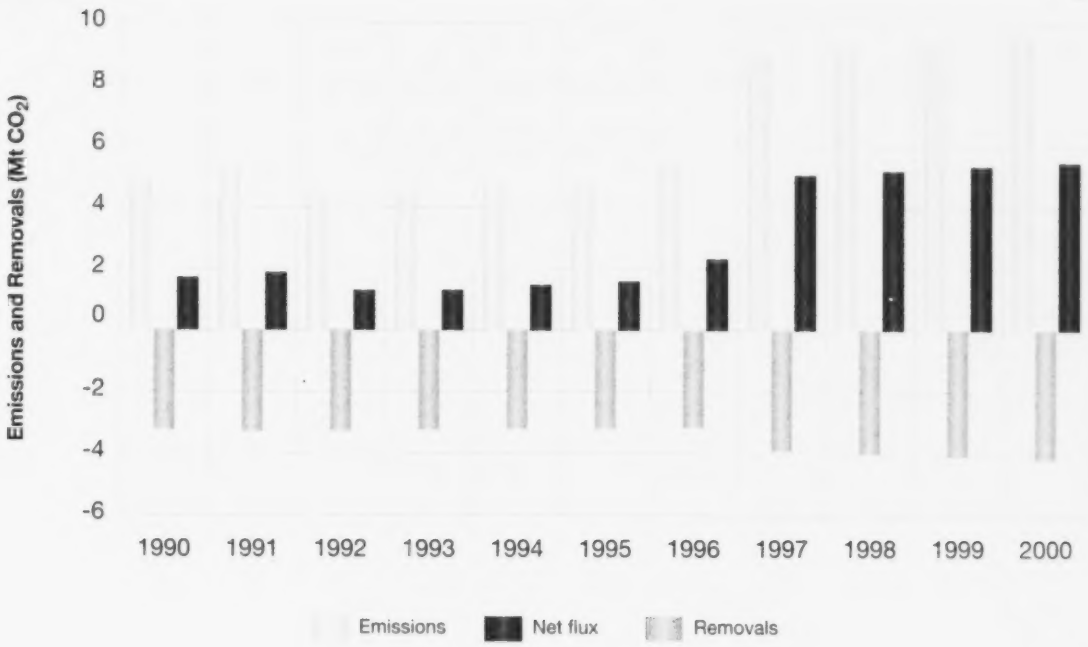
Figure 4 Trends in Carbon Dioxide Emissions and Removals Related to Land-use Changes in Canada, 1990 to 2000



from the levels of harvesting activities. In 1990, the net CO_2 removal in the LUCF sector totalled 61 Mt, while in 2000, the removal was only 16 Mt. Overall, the large decline in greenhouse gas removals in this sector over the decade is mirrored by a 18% increase in industrial roundwood production (Figure 3).

In 2000, the net flux associated with land-use changes in Canada resulted in emissions of over 5 Mt CO_2. These emissions have more than doubled between 1990 and 2000 (Figure 4).

Which Land-use Changes?

In the national inventory, land-use changes in Canada comprise the conversion of forests and grasslands to other land-uses (e.g. agriculture or urban lands), and the abandonment of agricultural lands which are assumed to revert back to their original vegetation cover.

Dynamics of Carbon Emissions and Removals

In general, forest and grassland conversion causes carbon emissions to the atmosphere. Carbon removals from the atmosphere are associated with vegetation regrowth on abandoned agricultural lands. The dynamics of carbon emissions and removals, however, operate at different time scales: emissions are immediate when large quantities of biomass are oxidized at once, or they can last longer when residues or soil organic matter decompose gradually. Conversely, carbon removals from the atmosphere and storage in living and dead organic matter is a slow process which spans decades, if not centuries. Consequently, for the purpose of greenhouse gas accounting, forest conversion and vegetation growth on abandoned lands cannot be treated as mirror processes.

Forest Fires

Canada's LUCF inventory only reports greenhouse gas emissions from fires caused by humans (also called *"anthropogenic"* fires). These emissions consist of carbon dioxide released from fires outside of the Wood Production Forest, as well as non-carbon dioxide emissions from all human-induced fires, regardless of location. Carbon dioxide emissions associated with fires inside the Wood Production Forest were discussed in the section on Forest Management. The non-carbon dioxide gases are methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), and carbon monoxide (CO).

The quantity of greenhouse gases released by forest fires varies annually with the extent of the area burned; therefore, it displays the large variability typical of natural disturbances (Figure 5). Over the period 1990 to 2000, annual emissions of greenhouse gases resulting from anthropogenic forest fires fluctuated between 2 and 17 Mt. The estimated area burned for 2000 is the average of the ten previous years, and, in view of the inter-annual variability noted above, should be treated with caution. This category is the only one for which non-carbon dioxide greenhouse gases are reported.

Uncertainty

While a reasonable degree of confidence can be placed on the overall trend direction, the flux estimates themselves are characterized by a high degree of uncertainty. To reflect this uncertainty, figures have been rounded (Environment Canada, 2001).

Forest Management

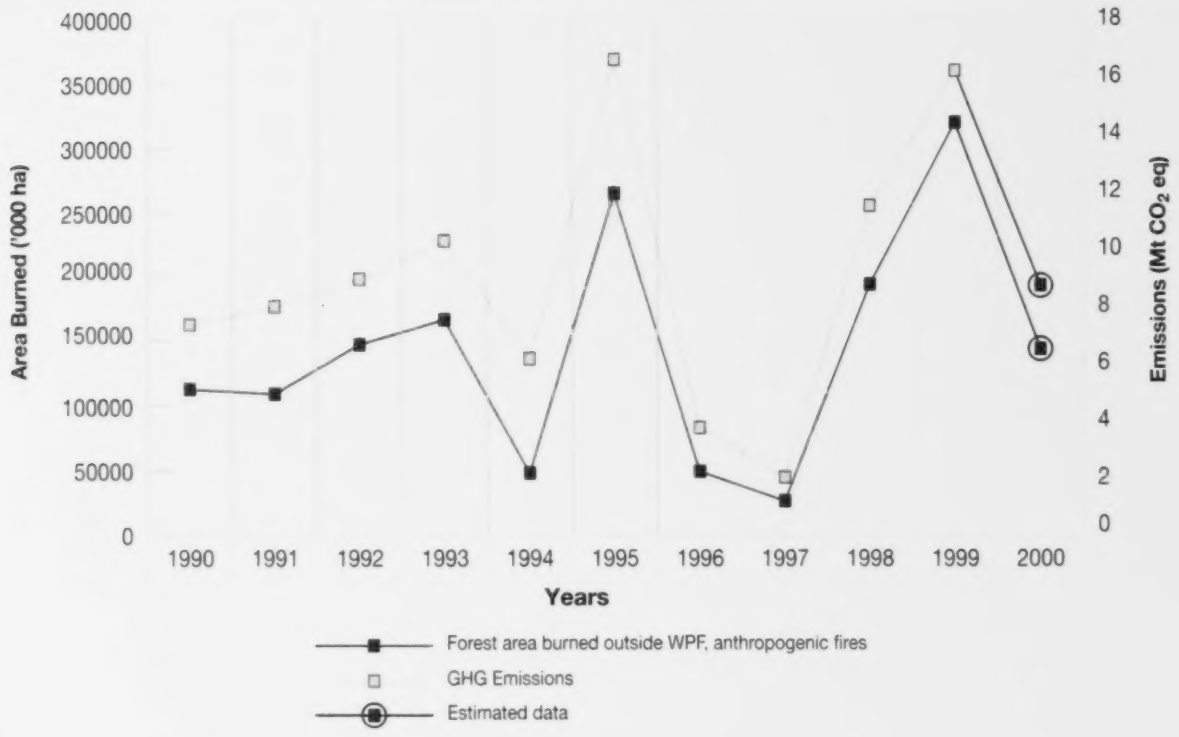
In view of the dominant influence of forest management on the net carbon flux in the LUCF sector, an analysis was conducted on the sensitivity of 1999 estimates to a selection of key parameters and data inputs.

Parameters that were modified in the course of the analysis were:

- area of the Wood Production Forest and its *"growing"* part;
- average rate of tree growth;
- harvest rates; and
- explicit account of carbon dioxide emissions from fires in the Wood Production Forest.

The three inputs with the largest influence on the total carbon removal by the Wood Production Forest are, in decreasing order of importance: carbon dioxide emissions from fires in the Wood Production Forest, tree growth rates, and the harvest rate. It is important to consider that the

Figure 5 Forest Area Burned and Total Greenhouse Gas Emissions from Anthropogenic Forest Fires, 1990 to 2000



relative significance of fire emissions in the Wood Production Forest vary annually, as do the location and extent of fires in all Canadian forests.

These results indicate that a priority for methodological improvement should be the development of better tools to estimate fire emissions from the Wood Production Forest. Efforts should also concentrate on a better assessment of biomass growth rates. It is believed that the overall improvement in accuracy obtained from better harvest data would be modest, given the relatively high confidence on the data quality.

The analysis omitted those unquantifiable and uncertain sources associated with insufficient knowledge or data. In particular, the magnitude of the net forest sink may be significantly altered by including the carbon content of dead organic matter in forest soils and litter, another large and poorly understood carbon pool. Work is on-going to incorporate this carbon pool in the model.

Land-Use Changes

Two major sources of uncertainty have been identified in carbon accounting of land-use changes: lack of data and information on land-use changes and land-use change practices; and, an incomplete understanding of soil carbon dynamics when land is converted to another use.

Missing data on land-use changes include the extent of the conversion, in each Canadian province, of natural ecosystems to agriculture, urban and industrial lands, rural residential land, as well as mining, petroleum and transportation infrastructure. Moreover, land-use change practices, such as burning, are poorly documented.

The current estimation methods for soil carbon emissions and removals due to land-use changes is based on the long-term average values of soil carbon content under different land uses. It is assumed that all soil carbon losses occur within twenty-five years, and all carbon sequestration on abandoned farmlands occurs within one hundred years.

Greenhouse gas accounting in Canada's LUCF sector is a complex and challenging task, due to the large land area, the myriad of human activities involved, and the intricate ways in which human activities and natural processes interact with each other. The inventory of greenhouse gas emissions and removals is an evolving process; in the coming years it will continue to strive for improved accuracy, completeness and transparency.

The Kyoto Protocol: Integrated LULUCF Reporting

The national greenhouse gas inventory is the ultimate measure against which Canada will be judged when reporting under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, or any similar, legally binding agreement.

Canada, if it ratifies the Kyoto Protocol, will see its reporting commitments greatly increased. The seventh Conference of the Parties to the UNFCCC, in November 2001, agreed that the accounting for the 2008-2012 reduction targets would include emissions and removals from afforestation, reforestation and deforestation (ARD) and optionally from forest management, cropland management, grazing land management, and revegetation activities. This provision would call for an integrated reporting of all greenhouse gas sources and sinks from land-based resources under the collective heading of Land Use, Land-use Change and Forestry (LULUCF) activities.

Environment Canada and all its partners in the federal, provincial, industry, non-governmental and academic communities are already organizing their resources to address the scientific and technical challenge of implementing the Kyoto reporting requirements.

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Data Sources:

1. Canadian Forest Inventory Publications
http://www.pfc.cfs.nrcan.gc.ca/monitoring/inventory/canfi/pubs_e.html

2. National Forestry Database maintained by the Canadian Council of Forest Ministers
http://nfdp.ccfm.org/frames2_e.htm

3. Census of Agriculture, compiled by Statistics Canada
http://www.statcan.ca/english/censusag/agri.htm

4. Food and Agriculture Organization of the U.N. (FAO) Forestry Database
http://apps.fao.org/cgi-bin/nph-db.pl?subset=forestry

Methodological Sources:

Environment Canada, *Canada's Greenhouse Gas Inventory 1990-2000*, June 2002.

Intergovernmental Panel on Climate Change (IPCC), Greenhouse *Gas Inventory Reporting Instructions*, Vol. 1; and *Greenhouse Gas Inventory Manual*, Vol. 3, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, 1997.

Glossary

Afforestation: the establishment of forests, through planting, seeding or other management activities, on land that has not been forested for a determined period of time.

Anthropogenic Forest Fires: forest fires caused by human activities, both intentional and accidental (also includes prescribed burning).

Biomass: the mass of living plant material, above-ground and below-ground.

Carbon flux: transfer of carbon from one pool to another.

Carbon pools: carbon reservoirs, with the capacity to accumulate or release carbon (e.g. forest biomass, wood products, soils and the atmosphere).

Carbon sequestration: the process of increasing the carbon content of a pool other than the atmosphere.

CO_2 equivalent: the amount of CO_2 that would cause the same atmospheric effect as a given amount or mixture of other greenhouse gases.

Emissions: the act of releasing a greenhouse gas to the atmosphere. Emissions come from sources.

Greenhouse gas: a gas that absorbs infrared radiation and in turn emits it in the atmosphere. The net effect is a local trapping of energy and a tendency to warm the earth's surface. Water vapour (H_2O), carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere.

IPCC Guidelines: guidelines developed by the Intergovernmental Panel on Climate Change for the preparation of national greenhouse gas inventories. The latest version was published in 1997.

Land Use: all arrangements, activities and inputs (sets of human actions) undertaken in a certain land cover type. The social and economic purpose for which land is managed (timber production, grazing, conservation).

Organic matter: carbon-based material that makes up the living tissues of plants and animals and their residues (litter, soil organic matter).

Removal: the act of removing a greenhouse gas from a pool. Removals from the atmosphere are done by sinks.

Sink: any process or mechanism which removes a greenhouse gas from the atmosphere. See also "removal".

Source: any process or mechanism which release a greenhouse gas in the atmosphere. The opposite of sinks.

Wood products: all products derived from the wood harvested from a forest. Includes fuelwood, logs and commodities derived from them (e.g. sawnwood, paper, woodchips, etc).

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CANADA'S GREENHOUSE GAS INVENTORY

GHG Trends Information from Environment Canada's Greenhouse Gas Division

Agriculture: 1990 - 2000

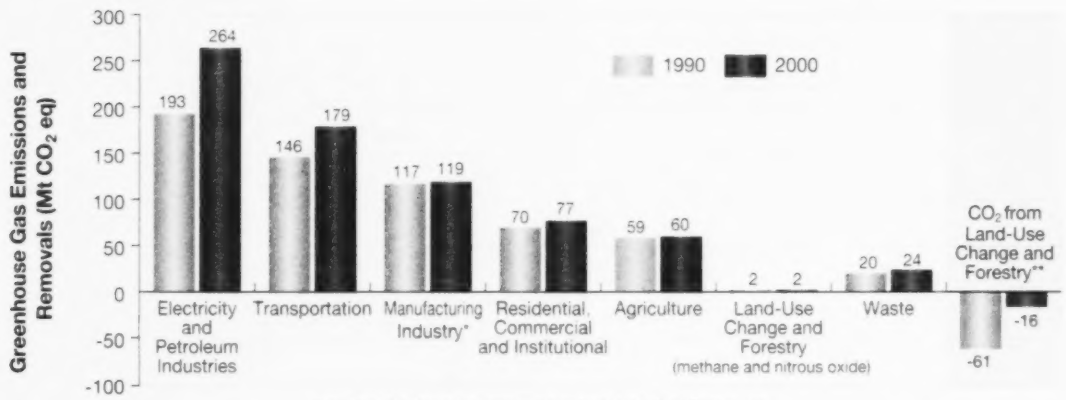
The Agriculture sector of the Canadian Greenhouse Gas Inventory (CGHGI) includes the contribution to greenhouse gas emissions from livestock, manure management, and agricultural soils.

- *In 2000,* greenhouse gas emissions from the Agriculture sector totaled 60.5 megatonnes of carbon dioxide equivalent* (Mt CO_2 eq) and contributed 8% towards total national emissions of 726 Mt. Agriculture accounted for 70% of Canada's total emissions of nitrous oxide, 25% of methane, and a small net sink of carbon dioxide. Nitrous oxide from agricultural soils contributed 55% of sectoral emissions in 2000 (33.4 Mt). Enteric fermentation emissions from domestic animals totaled 17.7 Mt and accounted for 29% of Agriculture emissions, while manure management contributed 16%, at 9.4 Mt.
- *Between 1990 and 2000,* total agricultural emissions rose 3%. If the carbon dioxide flux from agricultural soils is excluded**, total emissions from this sector would have increased 18% since 1990 (from 51.6 Mt to 60.7 Mt). On a category basis, emissions from manure management rose 13% and enteric fermentation emissions increased 11%. Net carbon dioxide emissions from agricultural soils decreased from 7.3 Mt in 1990 to -0.2 Mt in 2000 as a result of conservation tillage and reduced frequency of summer-fallow on the prairies. Nitrous oxide emissions from agricultural soils increased 23%, from 27.3 Mt in 1990 to 33.6 Mt in 2000.

*Unless otherwise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a measure of the impacts of different gases on global warming, with the effect of carbon dioxide being equal to one.

** The net flux of carbon dioxide is a combination of both the source and sink from agricultural soils.

Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000



*Value illustrated includes emissions due to Solvent and Other Product Use.

**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals.

Canada's Agriculture Sector

Many agricultural activities result in emissions of greenhouse gases. The processes that produce emissions are enteric fermentation in domestic animals, manure management systems, and cropping practices. While methane is produced through the enteric fermentation process, manure management systems generate both methane and nitrous oxide. Cropping practices can result in a release of carbon dioxide and nitrous oxide from soils.

The preparation of the Canadian Greenhouse Gas Inventory for the Agriculture sector closely follows the Guidelines published by the Intergovernmental Panel on Climate Change (IPCC, 1997). Accordingly, the inventory allocates greenhouse gas emissions by sources in the Agriculture sector within the following three categories:

1. Enteric Fermentation
2. Manure Management
3. Agricultural Soils

The remainder of this fact sheet will outline and discuss the major trends and underlying factors in greenhouse gas emissions for the Agriculture sector.

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Agriculture Sector Emission Trends : 1990 to 2000

Greenhouse gas emissions in the Agriculture sector rose 3% between 1990 and 2000, from 58.9 to 60.5 Mt.

Of the three greenhouse gas source categories within the Agriculture sector, the largest contribution of emissions is nitrous oxide from agricultural soils. This category represents approximately half of the sector's emissions in 2000, as well as throughout the 1990's (Figure 2).

Excluding the carbon dioxide flux from agricultural soils, total emissions from the Agriculture sector increased 18% since 1990 (from 51.6 Mt in 1990 to 60.7 Mt in 2000).

Enteric Fermentation

Emissions associated with enteric fermentation of animals accounted for 17.7 Mt in 2000, or nearly 30% of the total emissions within the Agriculture sector. Since 1990, emissions have increased 11%, mainly due to increased beef production.

The rising trend in greenhouse gas emissions from enteric fermentation is due to increases in cattle production. Non-dairy cattle production, which accounts for the highest emissions among the various types of cattle, has increased 21% since 1990 with a similar increase in emissions (Table 1).

What is enteric fermentation?

During the digestive process of herbivores, carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream, where methane is produced as a by-product. This process results in methane in the rumen, which is released by eructation and exhalation. Some methane is released later in the digestive process by flatulation. The animals that generate the most methane are ruminant animals such as cattle.

Canada's Agriculture Sector

Many agricultural activities result in emissions of greenhouse gases. The processes that produce emissions are enteric fermentation in domestic animals, manure management systems, and cropping practices. While methane is produced through the enteric fermentation process, manure management systems generate both methane and nitrous oxide. Cropping practices can result in a release of carbon dioxide and nitrous oxide from soils.

The preparation of the Canadian Greenhouse Gas Inventory for the Agriculture sector closely follows the Guidelines published by the Intergovernmental Panel on Climate Change (IPCC, 1997). Accordingly, the inventory allocates greenhouse gas emissions by sources in the Agriculture sector within the following three categories:

1. Enteric Fermentation
2. Manure Management
3. Agricultural Soils

The remainder of this fact sheet will outline and discuss the major trends and underlying factors in greenhouse gas emissions for the Agriculture sector.

The Canadian Greenhouse Gas Inventory (CGHGI)

The Canadian Greenhouse Gas Inventory is developed, compiled, and reported annually by the Greenhouse Gas Division of Environment Canada, and utilizes methods and models developed in-house by engineering and scientific staff, as well as published data, data developed by industry, or methods developed by the Intergovernmental Panel on Climate Change (IPCC, 1997).

The greenhouse gases that have been estimated in the national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).

The inventory uses an internationally agreed to reporting format that groups emissions and removals into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry, and Waste. The 2000 Trends Fact Sheet Series, while presenting the latest information on Canadian greenhouse gas emissions and removals derived from the latest national inventory, uses a modified sector approach to facilitate the use of information by the public.

Agriculture Sector Emission Trends : 1990 to 2000

Greenhouse gas emissions in the Agriculture sector rose 3% between 1990 and 2000, from 58.9 to 60.5 Mt.

Of the three greenhouse gas source categories within the Agriculture sector, the largest contribution of emissions is nitrous oxide from agricultural soils. This category represents approximately half of the sector's emissions in 2000, as well as throughout the 1990's (Figure 2).

Excluding the carbon dioxide flux from agricultural soils, total emissions from the Agriculture sector increased 18% since 1990 (from 51.6 Mt in 1990 to 60.7 Mt in 2000).

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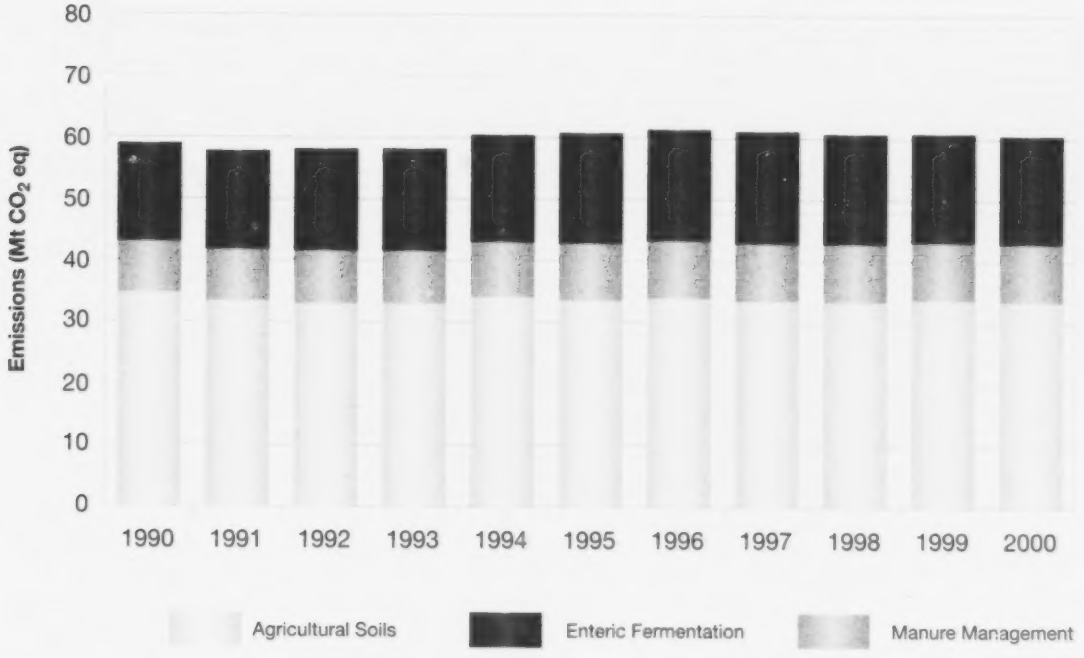
Figure 2 Agriculture Emissions by Category, 1990 - 2000



The increase in emissions from non-dairy cattle was partly offset by a reduction in emissions from dairy cattle, resulting from a decline in the number of dairy cows. Dairy cattle population decreased from 199,000 in 1990 to 160,600 in 2000 (Statistics Canada, #23-603).

Manure Management

During the handling and storage of livestock manure, both methane and nitrous oxide are emitted. The magnitude of the emissions is dependent upon the manure properties, quantities of manure, as well as the type of handling system. As for manure handling systems, poorly aerated ones generate more methane but little nitrous oxide, while well-aerated systems generate little methane but more nitrous oxide.

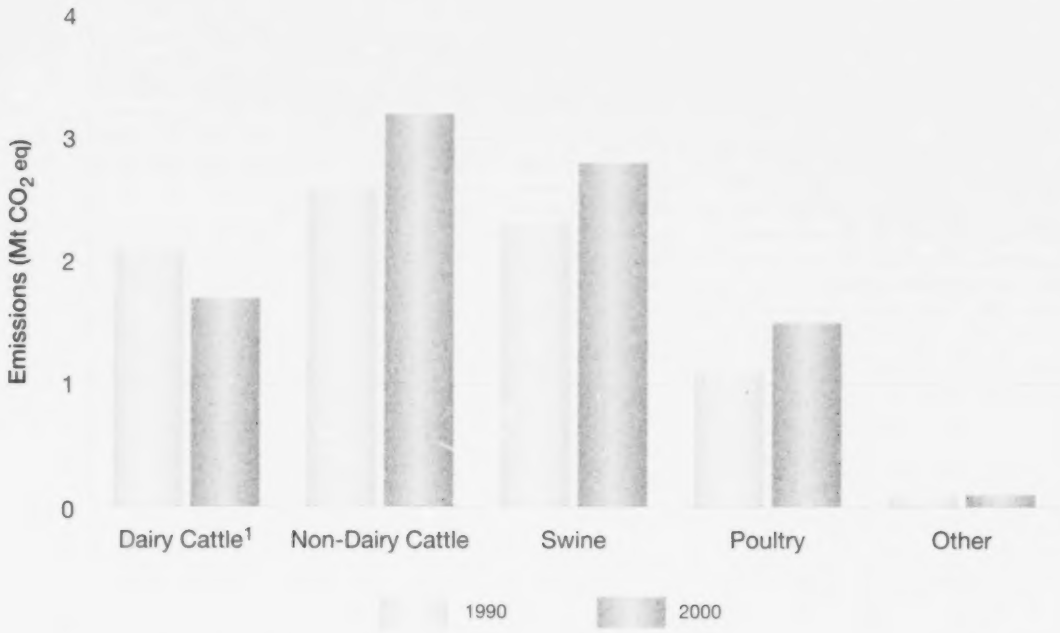
Nitrous oxide and methane emissions within this category have increased steadily since 1990 (Figure 3). Combined, these emissions increased 13% between 1990 and 2000, from 8.3 Mt to 9.4 Mt. The rising trend in emissions from manure management is mainly due to the expansion in the beef, swine and poultry industry.

Table 1 Enteric Fermentation Emissions by Category, 1990 and 2000, Mt CO_2 eq

Animal Type	1990	2000	% Change since 1990
Dairy Cattle[1]	4.1	3.4	-17%
Non-Dairy Cattle	11.3	13.6	20%
Swine	0.3	0.4	33%
Other	0.3	0.3	0%
Total	**16.0**	**17.7**	**11%**

[1]Dairy cattle includes dairy heifer

Figure 3 Combined Nitrous Oxide and Methane Emissions from Manure Management, 1990 and 2000



[1]Dairy cattle includes dairy heifer

Agricultural Soils

Greenhouse gas emissions from agricultural soils in Canada totaled 33.4 Mt in 2000. This represents a 3% reduction in emissions over the 1990 estimate of 34.6 Mt. If the carbon dioxide flux from agricultural soils is excluded, total emissions from this category increased 24%, from 27.3 Mt in 1990 to 33.6 Mt in 2000.

Soil management and cropping practices affect both carbon and nitrogen cycles in soils. These management practices can lead to emissions and removals of carbon dioxide, as well as emissions of nitrous oxide. For example, both conservation tillage and reducing the frequency of summer-fallowed fields can lead to increased carbon storage in soils. Conversely, uses of nitrogen fertilizer and manure on agricultural soils lead to emissions of nitrous oxide. Table 2 outlines the trends in both nitrous oxide and carbon dioxide emissions from agricultural soils for the period 1990 to 2000.

Carbon Dioxide

Net carbon dioxide emissions from agricultural soils have decreased significantly from 7.3 Mt in 1990 to -0.2 Mt in 2000. The primary reason for the reduced net emissions from soils is due to the increasing practice of conservation tillage and reduced frequency of summer-fallow on the prairies. In particular, no-till farming was practiced on over 16% of Canada's annual croplands in 1996 (Statistics Canada, #93-356), as opposed to 7% in 1991 (Statistics Canada, #93-350).

Nitrous Oxide

Nitrous oxide emissions have increased 23% between 1990 and 2000 (from 27.3 Mt to 33.6 Mt). Emissions of nitrous oxide can be subdivided into direct and indirect sources. Direct emissions are those that are emitted directly from agricultural fields, while indirect emissions are those that are emitted off site by either volatilization and subsequent redeposition or by leaching and runoff.

Direct Sources

The direct sources of nitrous oxide emissions from agricultural soils are:

- *synthetic nitrogen fertilizers:* nitrous oxide emissions from the application of synthetic nitrogen fertilizers have increased steadily from 6.5 Mt in 1990 to 9.2 Mt in 2000, representing an increase of approximately 42%.
- *animal wastes applied as fertilizer:* emissions due to animal manure used as fertilizers on agricultural soils have increased from 3.2 to 3.7 Mt, resulting from an expansion of the national livestock industry.
- *grazing animals:* emissions associated with the application of manure to soils through grazing animals increased from 2.3 to 2.7 Mt between 1990 and 2000 due to the increased livestock population.
- *plant biological nitrogen fixation:* leguminous crops such as alfalfa, soybean and lentil can fix atmospheric nitrogen, but the ribozobia in plant nodules of these crops can emit nitrous oxide as they fix nitrogen. Nitrous oxide emissions from the production of leguminous crops remained relatively unchanged during the last decade at about 4 Mt per year.
- *crop residue decomposition:* after a crop is harvested, a portion of the crop is left on the field to decompose. The remaining plant matter is a source of nitrogen. Nitrous oxide emissions through crop residue decomposition increased over the period 1990 to 2000 from 6.0 to 6.6 Mt.
- *cultivation of histosols:* nitrous oxide is emitted as a result of cultivating organic soils, also known as histosols, for annual crop production. There is no detailed agricultural census data available on the area of cultivated histosols in Canada. In light of this, through consultation with soils and crops specialists, the area of cultivated histosols is estimated to be approximately 30,000 hectares. Emissions from this source are small and remain unchanged at 0.01 Mt per year.

Table 2 Agricultural Soil Emissions by Category, 1990 - 2000, Mt CO_2 eq

Greenhouse Gas Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon Dioxide Total	**7.3**	**6.7**	**5.8**	**4.7**	**4.2**	**3.2**	**1.8**	**1.2**	**0.7**	**0.2**	**-0.2**
Nitrous Oxide											
Synthetic Fertilizer Nitrogen	6.5	6.4	6.9	7.2	7.7	7.9	8.6	9.1	9.1	8.9	9.2
Manure as Fertilizer	3.2	3.2	3.3	3.3	3.5	3.6	3.6	3.6	3.7	3.7	3.7
Grazing Animals	2.3	2.4	2.4	2.4	2.6	2.7	2.7	2.8	2.7	2.7	2.7
Biological Nitrogen Fixation	3.8	3.6	3.4	3.8	4.3	3.9	3.8	3.6	3.8	4.4	4.4
Crop Residue Decomposition	6.0	5.7	5.4	5.6	5.4	5.9	6.5	6.0	6.4	6.8	6.6
Cultivation of Histosols	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Indirect Nitrous Oxide	5.4	5.4	5.7	5.8	6.2	6.4	6.7	7.0	6.9	6.9	7.0
Nitrous Oxide Total	**27.3**	**26.6**	**27.1**	**28.2**	**29.8**	**30.3**	**32.1**	**32.2**	**32.6**	**33.4**	**33.6**
Greenhouse Gas Emissions Total	**34.6**	**33.3**	**32.9**	**32.9**	**34.0**	**33.5**	**33.9**	**33.4**	**33.3**	**33.6**	**33.4**

Indirect Sources

A fraction of the nitrogen fertilizer that is applied to agricultural fields will be transported off site by both volatilization and subsequent redeposition or by leaching and runoff. The nitrogen that is transported from the agricultural field will provide an additional source of nitrogen for nitrous oxide emissions.

Indirect emissions of nitrous oxide increased substantially from 5.4 Mt in 1990 to 7.0 Mt in 2000. This increase is attributed to both the expansion of the livestock industry, as well as to an increased consumption of synthetic nitrogen fertilizers.

Summary of Non-Carbon Dioxide Trends in Agricultural Emissions

In this section, greenhouse gas emissions within the Agriculture sector are alternatively classified as either animal or crop production-related. Emissions associated with animal production include enteric fermentation, manure management and manure disposal. Crop production emissions include greenhouse gases from both direct and indirect sources as described in the previous section.

Excluding the carbon dioxide flux from agricultural soils, animal production contributed between 60 to 65% of the total sectoral emissions, while crop production accounted for 35 to 40% of emissions (Table 3).

Animal Production

Approximately one half of emissions related to animal production in Canada result from enteric fermentation, while the other half is equally split between manure management and on-land use of manure as fertilizers.

Major contributors of greenhouse gases among domestic animals in Canada are non-dairy cattle, dairy, swine, and poultry. Since 1990, emissions associated with non-dairy cattle increased 21%, swine by 19% and poultry by 27%, while dairy production-related emissions decreased 24%. Contributions of emissions from other domestic animals remain unchanged for the period.

Table 3 Summary of Major Non-Carbon Dioxide Emissions Resulting from Animal and Crop Production in Canada, Mt CO_2 eq

Greenhouse Gas Source	1990	1993	1996	2000
Animal Production[a] (percent of annual Total)				
Non-Dairy[b]	18.5 (36%)	20.2 (38%)	22.5 (38%)	22.4 (37%)
Dairy[c]	8.0 (16%)	7.3 (14%)	7.4 (12%)	6.5 (11%)
Swine	3.7 (7%)	3.9 (7%)	4.4 (7%)	4.4 (7%)
Poultry	2.6 (5%)	2.7 (5%)	3.1 (5%)	3.3 (5%)
Crop Production (percent of annual Total)				
Synthetic Nitrogen Fertilizers[d]	9.3 (18%)	10.2 (19%)	12.3 (21%)	13.1 (22%)
Crop[e]	9.8 (19%)	9.4 (18%)	10.3 (17%)	11.1 (18%)

[a] Also includes manure used as fertilizer
[b] Percent of total Agriculture Sector non-carbon dioxide emissions
[c] Dairy cattle includes dairy heifer
[d] Includes both direct and indirect sources
[e] Includes Biological Nitrogen Fixation and Crop Residue Decomposition

Crop Production

While non-carbon dioxide emissions have increased during the 1990 to 2000 period, the contributions of the major emission sources remained relatively unchanged.

While the contribution of nitrous oxide emissions, resulting from the consumption of synthetic nitrogen fertilizers, only increased from 18 to 22% of the total nitrous oxide emissions, the consumption of synthetic nitrogen fertilizer increased by nearly 40% between 1990 and 2000. Emissions associated with legume and non-leguminous crops, as well as crop residue decomposition, collectively contributed between 16 and 19% of Canada's Agriculture sector emissions.

Provincial Non-Carbon Dioxide Agricultural Emissions

Since 1990 there has been very little change in non-carbon dioxide emissions in British Columbia, Ontario, Quebec, and Atlantic regions of Canada. From 1990 to 2000, however, non-carbon dioxide emissions increased steadily from 5.6 to 7.2 Mt in Manitoba, from 8.9 to 13.4 Mt in Saskatchewan, and from 14.2 to 17.3 Mt in Alberta. Table 4 highlights the provincial trends in non-carbon dioxide emissions between 1990 and 2000.

The increased emissions from the prairie provinces resulted from livestock expansion and synthetic nitrogen fertilizer consumption, and contributed to nearly all increases in Canada's greenhouse gas emissions from the Agriculture sector since 1990.

Table 4 Summary of Provincial Non-Carbon Dioxide Greenhouse Gas Emissions in the Agriculture Sector, Mt CO_2 eq[1]

Province	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Newfoundland	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Prince Edward Island	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Nova Scotia	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New Brunswick	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Quebec	7.8	7.3	7.3	7.5	7.6	7.8	7.9	7.8	7.8	7.7	7.7
Ontario	11.2	11	10.8	10.8	11.1	11.2	10.8	11.1	11.2	11.2	11
Manitoba	5.6	5.8	6.1	6.1	6.5	6.7	7.2	7	7.3	7.1	7.2
Saskatchewan	8.9	9	9.7	10	10.9	11.5	12.7	13.1	12.9	12.9	13.4
Alberta	14.2	14.3	14.4	15.1	15.9	16.4	16.7	16.5	16.8	17.5	17.3
British Columbia	2.4	2.3	2.4	2.5	2.6	2.6	2.7	2.7	2.5	2.6	2.5
CANADA	**51.6**	**51.1**	**52.1**	**53.4**	**56.2**	**57.6**	**59.6**	**59.8**	**59.9**	**60.6**	**60.7**

[1] Numbers may not add up to totals due to rounding

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CANADA'S GREENHOUSE GAS INVENTORY
GHG Trends Information from Environment Canada's Greenhouse Gas Division

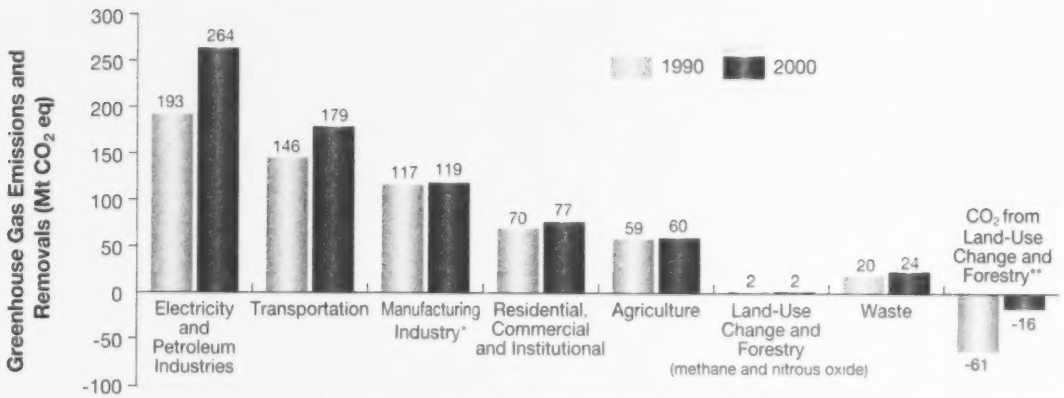
Waste: 1990-2000

The Waste sector of the Canadian Greenhouse Gas Inventory (CGHGI) includes the contribution to greenhouse gas emissions from solid waste disposal on land, wastewater handling and waste incineration.

- *In 2000*, greenhouse gas emissions from the Waste sector totalled 24 megatonnes carbon dioxide equivalent* (Mt CO_2 eq), representing about 3% of Canada's total emissions (726 Mt) in 2000. The primary source of emissions is from solid waste disposal on land, which contributed 93% of the total sector emissions, with much smaller contributions from wastewater handling and waste incineration (6% and 1%, respectively). The majority of emissions were methane (CH_4), at 23 Mt, with the remainder being composed of nitrous oxide (N_2O) (1 Mt) and carbon dioxide (0.3 Mt).
- *Between 1990 and 2000*, waste-related emissions rose by 21%, of which 96% of the increase is attributable to a rise in landfill emissions. Waste incineration and wastewater handling emissions increased 10% and 11%, respectively, and generally follow the national population trend. Although emissions from solid waste disposal on land rose 22%, increasing landfill gas capture decreased the rate of emission growth from landfills in the early to middle 1990s.

*Unless otherwise indicated, all emissions are reported in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a relative measure of the impacts of different greenhouse gases on global warming, with the effect of carbon dioxide being equal to one.

Figure 1 Canadian Greenhouse Gas Emissions and Removals, 1990 and 2000



*Value illustrated includes emissions due to Solvent and Other Product Use

**Carbon dioxide emissions from the Land-Use Change and Forestry sector are not included in the national inventory totals.

Canada's Waste Sector

The major sources of greenhouse gas emissions in the Waste sector are solid waste disposal in landfills, wastewater handling and waste incineration. These emissions consist almost completely of methane; in fact, methane emissions comprised 95% of the total emissions in this sector in 2000.

Much of the waste treated or disposed is biomass-based. The carbon dioxide emissions attributable to such wastes are not included in the national inventory totals, but are accounted for when measuring changes in carbon in the Agriculture and Land-Use Change and Forestry sectors. In theory, there are no net emissions if the biomass is sustainably produced and consumed. This assumes that, on an annual basis, the carbon dioxide emitted from the decomposition of food is consumed in growing the next year's crop. Carbon dioxide emissions from the disposal of paper and wood are not included in the Waste sector, but are accounted for in the Land-Use Change and Forestry sector.

The Greenhouse Gas Inventory allocates emissions from the Waste sector within the following three categories:

1. Solid Waste Disposal on Land
2. Wastewater Handling
3. Waste Incineration

The Canadian Greenhouse Gas Inventory (CGHGI)

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Waste Sector Emission Trends: 1990 to 2000

Greenhouse gas emissions from the Waste sector totalled 24 Mt, representing 3% of Canada's total emissions in 2000. Waste-related emissions rose by 21% since 1990, of which 96% of this increase is attributable to increases in landfill emissions. Figure 2 compares the changes in emissions among the Waste sector categories for 1990 and 2000.

In 2000, Solid Waste Disposal on Land accounted for about 93% of the emissions in this sector, while Municipal Wastewater and Incinerated Material derived from fossil-fuel products are minor contributing categories (6% and 1%, respectively). Of the sector's 24 Mt of emissions, 23 Mt were composed of methane.

Solid Waste Disposal on Land

Emissions from Solid Waste Disposal on Land were 23 Mt in 2000, an increase of 22% since 1990. Solid waste disposal on land was the second largest source category of methane emissions in Canada, accounting for 25% of the national total for methane.

Emissions are estimated for two types of landfills in Canada: municipal solid waste (MSW) landfills and forest industry landfills. Most waste disposal on Canadian land occurs in municipally managed or privately owned landfills. Very few, if any, unmanaged waste disposal sites exist; therefore, it has been assumed that all waste is disposed of in managed facilities. Residential, institutional, commercial, industrial, construction and demolition wastes are disposed of in MSW landfills. Forestry industry landfills are privately owned and typically operated by forest industries such as saw mills and pulp and paper mills. These industries used the landfills to dispose of surplus wood residue such as bark sawdust and wood shavings. Today, forest industry landfilling is restricted to the diposal of wastewater sludges and boiler ash.

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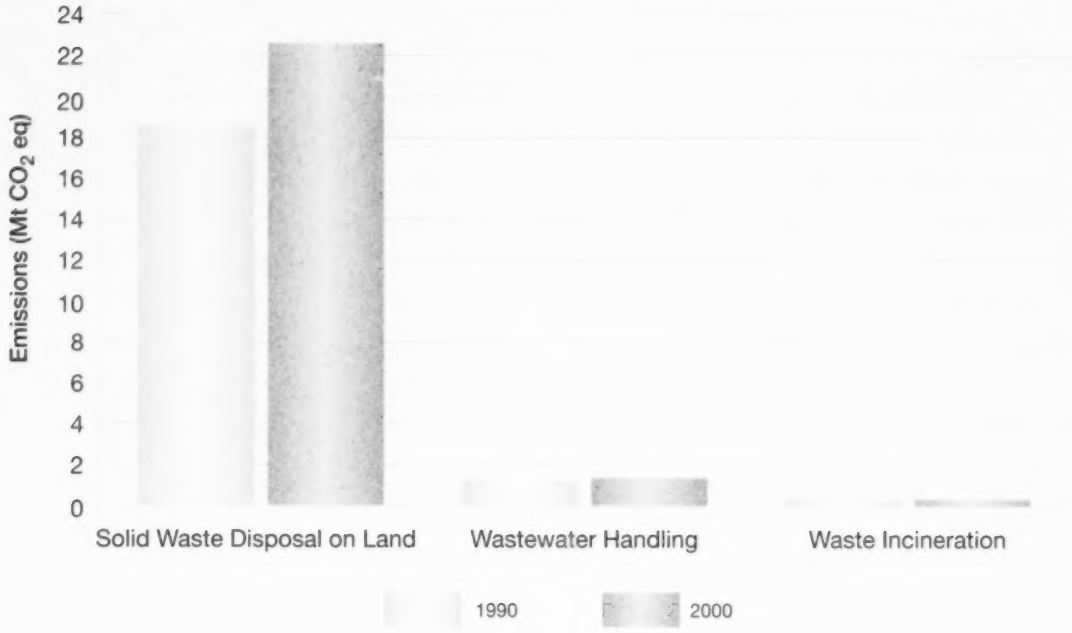
Figure 2 Greenhouse Gas Emission Trends in the Waste Sector by Subcategory, 1990 and 2000



In Canada, there are well over ten thousand landfill sites (Levelton,1991). Landfill gas, which is composed mainly of methane and carbon dioxide, is produced by the anaerobic decomposition of organic wastes. The first phase of this process typically begins after waste has been in a landfill for ten to fifty days. Although the majority of methane and carbon dioxide is generated within twenty years of landfilling, emissions can continue for one hundred years or more (Levelton, 1991). This means that emissions estimated in any one year are not only the result of landfilled waste from the previous year, but also from waste that was landfilled decades earlier.

The generation of methane from MSW landfills has increased since 1990 (Figure 3), however, more landfill gas is now being captured and combusted. Landfill gas capture is not typically practised at forest industry landfills due to low decomposition rates.

The net methane emissions from landfills are determined from the following equation:

Total methane from landfills = methane produced - methane captured

Table 1 provides a breakdown of methane emissions originating from both MSW and forest industry landfills for the period 1990 to 2000. Net emissions from MSW landfills have increased 22% since 1990 and for all years represent over 90% of the total emissions in this category. Compared with MSW landfills, forest industry landfills are a minor source of methane emissions. Emissions from forest industry landfills rose 21% over the period, largely due to the cumulative effect of emissions from historical deposits.

A more detailed breakdown of emissions associated with MSW landfills is given in Figure 3. As indicated above, landfill gas recovery is practised at a number of MSW landfills in Canada. As of December 1999, 42 landfills conducted landfill gas recovery programs (Environment Canada, 2000). Of the 27 Mt of methane generated in MSW landfills in 2000,

Figure 4 Per Capita Greenhouse Gas Emissions Trend for Waste, 1990 to 2000

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22% (5.9 Mt) of this methane was captured, resulting in net emissions of 21 Mt to the atmosphere. Over the entire 1990 to 2000 period, landfill gas capture increased 33%.

In spite of this trend, net methane emissions from landfills increased 22% over the decade, mainly due to emission contributions from waste that was landfilled years to decades earlier.

Table 1 Methane Emission Trends from Landfills, 1990 to 2000 (Mt CO_2 eq)

Year	Municipal Solid Waste[1]	Wood Waste	Total Emissions
1990	17	1.5	19
1991	18	1.6	19
1992	18	1.6	20
1993	18	1.7	20
1994	19	1.7	20
1995	19	1.8	20
1996	19	1.8	20
1997	19	1.9	21
1998	20	1.9	21
1999	20	1.8	22
2000	21	1.8	23

Note: Due to rounding, individual values may not add up to the totals.

[1] Emissions from MSW landfills represent net emissions (total emissions generated, less emissions that were captured through landfill gas capture programs).

Figure 3 Methane Generation, Capture and Net Emission Trends from MSW Landfills, 1990 to 2000

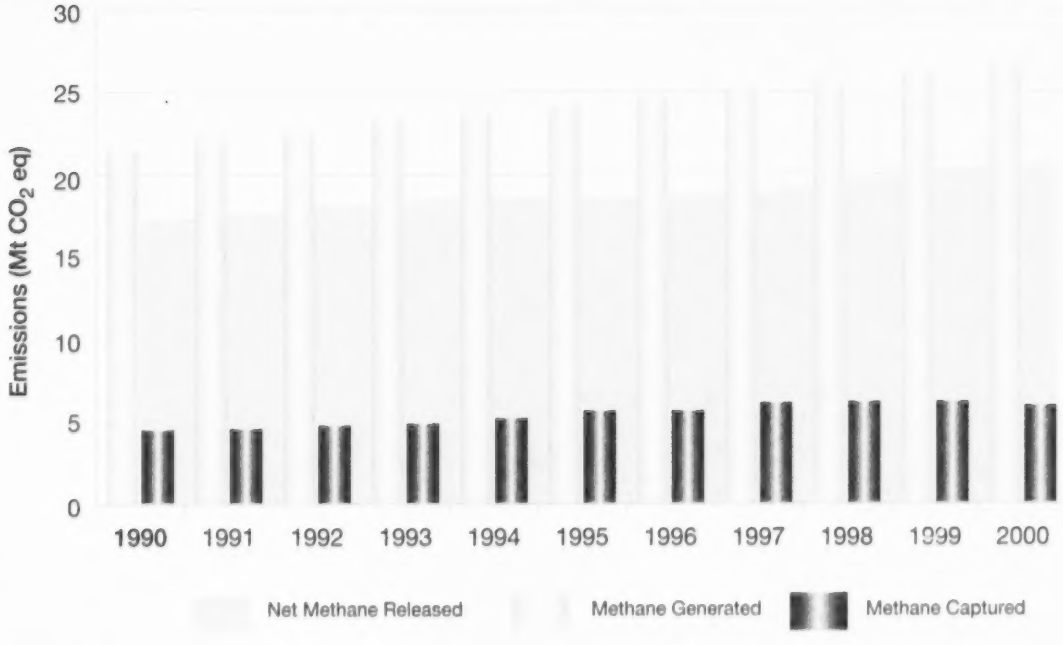

Table 2 Greenhouse Gas Emission Trends for Wastewater Treatment, 1990 to 2000 (Mt CO_2 eq)

Year	Methane	Nitrous Oxide	Total
1990	0.36	0.87	1.2
1991	0.36	0.88	1.2
1992	0.36	0.89	1.3
1993	0.37	0.90	1.3
1994	0.37	0.91	1.3
1995	0.38	0.92	1.3
1996	0.38	0.93	1.3
1997	0.39	0.94	1.3
1998	0.39	0.95	1.3
1999	0.40	0.95	1.3
2000	0.40	0.96	1.4

Note: Due to rounding, individual values may not add up to the totals.

Wastewater Handling

Emissions from wastewater handling totalled 1.4 Mt in 2000, an increase of 11% since 1990. The emissions have essentially followed the same trend as Canada's population during this period.

Municipal wastewater can be aerobically or anaerobically treated. When wastewater is treated anaerobically, methane is produced. Emissions from aerobic systems are assumed to be negligible. Both types of systems generate nitrous oxide through the nitrification and denitrification of sewage nitrogen (IPCC, 1997). Carbon dioxide is also generated by both types of treatment but, as discussed earlier, carbon dioxide emissions originating from the decomposition of food are not inventoried.

Waste Incineration

Emissions from both MSW and sewage sludge incineration are included in the inventory. While emissions from waste incineration were a minor source of greenhouse gases in 2000 (0.3 Mt) emissions from this category have increased by nearly 10% since 1990, the majority from MSW incineration. In common with emissions from wastewater handling, waste incineration emissions mirror the trends in population growth in Canada.

Several municipalities in Canada utilize incinerators to reduce the quantity of MSW sent to landfills and to reduce the amount of sewage sludge requiring land application. The greenhouse gas emissions from incinerators depend on factors such as: the amount of waste incinerated, the composition of the waste, the carbon content of the non-biomass waste, and the facilities' operating conditions.

Waste Emissions Per Capita

Waste emissions per capita increased 9% from 1990 to 2000, primarily due to the increasing emissions from landfills (Figure 4). Growth in emissions exceeded population increases during this period because material that was landfilled in past decades is still contributing to methane production today. The decline in per capita growth in emissions observed in the mid-1990s is attributable to an increase in methane recovery at landfills, which rose 33% between 1990 and 2000.